Volume 15 FEBRUARY 5, 1940 No. 1

# BULLETIN

Bureau of Standards

FEB 7 1940

OF THE

## AMERICAN PHYSICAL SOCIETY

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PROGRAM

FOR THE

NEW YORK MEETING

FEBRUARY 21–24, 1940

JOINT MEETING

WITH THE

OPTICAL SOCIETY OF AMERICA

at

COLUMBIA UNIVERSITY

and the

INTER-SOCIETY COLOR COUNCIL

at

THE ROOSEVELT HOTEL AND
480 LEXINGTON AVENUE

For Program of sessions of the Physical Society see Pages 6 to 23.
For Program of sessions of the Optical Society see Pages 24 to 28.
For Program of sessions of the Inter-Society Color Council see Pages 29 to 33.

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SEVEN ISSUES EACH YEAR

# The American Physical Society

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# BULLETIN

of the

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FEBRUARY 5, 1940 Vol. 15, No. 1

# BULLETIN

OF THE

# AMERICAN PHYSICAL SOCIETY

NEW YORK MEETING, FEBRUARY 21–24, 1940

JOINT MEETING

WITH THE

OPTICAL SOCIETY OF AMERICA

AND THE

INTER-SOCIETY COLOR COUNCIL

THE 233rd regular meeting of the American Physical Society will be held in New York City as a joint meeting with the Optical Society of America and the Inter-Society Color Council. The sessions of the American Physical Society and of the Optical Society of America will be held on Friday and Saturday, February 23 and 24, at Columbia University in the Pupin Physics Laboratories. The sessions of the Inter-Society Color Council will be held on Wednesday and Thursday, February 21 and 22, at the Roosevelt Hotel and at 480 Lexington Avenue.

**Joint Session.** A joint session of the American Physical Society, the Optical Society of America and the Inter-Society Color Council will be held on Friday morning, February 23, at ten o'clock in the Pupin Physics Laboratories, Room 401. A special symposium of invited papers on "Optical Methods for the Study of Molecular Structure" will be presented.

**Dinner.** A joint dinner of the three societies will be held on Friday evening, February 23, at six-fifteen o'clock, at the Columbia University Men's Faculty Club, on 117th Street near Morningside Drive. The President of the Physical Society, Professor John Zeleny of Yale University, will preside. The price of the dinner will be $1.25 per plate. Tickets will be on sale at the Pupin Physics Laboratories, Columbia University. Reservations must be made not later than three P.M. on Friday.

**Luncheon.** On Friday and Saturday luncheon may be had at the Columbia University Men's Faculty Club. Further announcement will be made at the Friday and Saturday sessions.

## GENERAL RULES RELATING TO PAPERS

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

On December 28, 1936, the Society voted that:

> No papers may be accepted for presentation at any meeting of the Society subsequent to the closing date stated in the printed call for that meeting.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.)

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to these papers

or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Publications Manager, The American Institute of Physics Incorporated, 175 Fifth Avenue, New York, N. Y.

Other meetings for the current season are as follows:

234. April 25–27, 1940. Washington, D. C.
235. June 19–21, 1940. Seattle, Washington, Pacific Coast meeting.
236. June, 1940. Summer meeting. Place and time not yet decided.
237. November, 1940. Chicago, Illinois.
238. December, 1940. Pacific Coast.
239. December 27, 1940–January 2, 1941. Annual Meeting. Philadelphia, Pennsylvania.
240. February, 1941. Cambridge, Massachusetts.

W. L. SEVERINGHAUS, *Secretary*
*Columbia University, New York, N. Y.*

February 5, 1940.

## CALENDAR

Wednesday afternoon, February 21

2:00 o'clock: Roosevelt Hotel: Hendrick Hudson Room: Technical session on Spectrophotometry in the Pulp and Paper Industry: Jointly sponsored by the Inter-Society Color Council and the Technical Association of the Pulp and Paper Industry. See pages 29–31.

Wednesday evening, February 21

8:00 o'clock: 480 Lexington Avenue: Auditorium: Popular session on *Parade of Color:* Inter-Society Color Council. See page 31.

Thursday morning, February 22

9:30 o'clock: Roosevelt Hotel: Hendrick Hudson Room: Discussion session. See page 32.

Thursday afternoon, February 22

1:00 o'clock: Roosevelt Hotel: Hendrick Hudson Room: Luncheon groups to continue informal discussion.

2:30 o'clock: Roosevelt Hotel: Hendrick Hudson Room: Business session of the Inter-Society Color Council.

Friday morning, February 23

10:00 o'clock: Pupin Physics Laboratories: Room 401: Joint session of American Physical Society, Optical Society of America and Inter-Society Color Council: *Symposium on Optical Methods for the Study of Molecular Structure.* See pages 6, 24, 33.

Friday afternoon, February 23

2:00 o'clock: Pupin Physics Laboratories: Room 401: Physical Society papers 1–13. See pages 6–9.

2:00 o'clock: Pupin Physics Laboratories: Room 329: Physical Society papers 14–25. See pages 9–12.

2:00 o'clock: Pupin Physics Laboratories: Room 428: Optical Society papers 1–5. See pages 24–26.

2:30 o'clock: Pupin Physics Laboratories: Room 818: Meeting of the Council of the Physical Society.

Friday evening, February 23

6:15 o'clock: Columbia University Men's Faculty Club: Joint dinner of the societies.

Saturday morning, February 24

10:00 o'clock: Pupin Physics Laboratories: Room 401: Physical Society papers 26–37. See pages 12–14.

10:00 o'clock: Pupin Physics Laboratories: Room 329: Physical Society papers 38–51. See pages 14–17.

10:00 o'clock: Pupin Physics Laboratories: Room 428: Optical Society papers 6–9. See pages 26–27.

Saturday afternoon, February 24

2:00 o'clock: Pupin Physics Laboratories: Room 401: Physical Society papers 52–63. See pages 18–20.

2:00 o'clock: Pupin Physics Laboratories: Room 329: Physical Society papers 64–74. See pages 21–23.

2:00 o'clock: Pupin Physics Laboratories: Room 428: Optical Society papers 10–13. See pages 27–28.

# The American Physical Society

## PROGRAM

FRIDAY MORNING AT 10:00 O'CLOCK

Pupin Physics Laboratories, Room 401

*Joint Session of the American Physical Society, the Optical Society of America and the Inter-Society Color Council*

**SYMPOSIUM**

**ON**

**OPTICAL METHODS FOR THE STUDY OF MOLECULAR STRUCTURE**

Invited Papers

1. **The X-Ray Diffraction Method.** B. E. WARREN, *Massachusetts Institute of Technology.*
2. **The Electronic Diffraction Method.** LOUIS R. MAXWELL, *Department of Agricultural Chemistry and Engineering of the U. S. Department of Agriculture.*
3. **The Band Structure Method.** R. BOWLING BARNES, *The American Cyanamid Company.*
4. **The Raman Spectra Method.** GEORGE M. MURPHY, *Yale University.*

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FRIDAY AFTERNOON AT 2:00 O'CLOCK

Room 401

(For simultaneous session of the Optical Society, Room 428, see pages 24–26)

**1. Wilson Cloud Chamber for Cosmic Rays.** RALPH P. SHUTT, *Bartol Research Foundation of the Franklin Institute. (Introduced by T. H. Johnson.)*—A quadrangular cloud chamber was built with both front and back walls of glass. This could be expanded on two sides, so as to create a zone of minimum disturbance in the center. In order to reduce the weight of the chamber so that it might easily be dropped down for the purpose of taking it out of magnetic fields and of avoiding turbulences by gravity, its main body was made of aluminum. The two valves worked according to the knee principle so that a weak electromagnet with a low time constant was sufficient to keep them closed. Illumination was provided by two spark gaps of atmospheric air, each adjusted for breakdown at 30,000 volts. A 4,5 $\mu$f condenser charged with only 30,000 volts was discharged through both in series; this became possible by inserting a resistance between one side of the condenser and the wire connecting the two gaps. The arrangement furnished about 1.7 times as much light as one spark with the same energy. Each spark cast its light at an angle of 20° to the axis of the chamber. Photographs were taken at $f:9$ to $f:12$. Expansion was complete 1/600 sec. after the ray had passed through the chamber, and the breadth of tracks was $\frac{1}{3}$ mm.

**2. Shower Production by Mesotrons in Different Material.** W. F. G. SWANN AND W. E. RAMSEY, *Bartol Research Foundation of the Franklin Institute.*—A sextuple coincidence set of Geiger counter sensitive areas was employed with a large thickness of metal below the upper area. Shower production was observed in the lower areas with an apparatus already described.[1] Five hundred and thirty pictures were taken for lead and for tin, while 2000 pictures were taken for magnesium, the experiments being continually in progress. Estimated per 1000 pictures, the number of doubles for lead, tin, and magnesium are in the ratio of 1, 1.41, 1.68, the actual numbers per 1000 pictures being, respectively, 34, 48, 57, thus indicating that the shower production, as regards doubles, is progressively less with increasing atomic number. The conclusion will doubtless be enhanced in reliability when more data are secured. The distinction between the different metals appears to diminish with the number of shower rays. Thus, taking all shower rays greater than two, the numbers are in the ratio of 1 to 0.9 to 1.2. It may be remarked that the whole experiment was carried out below a tank filled with 30 feet of water. These results are not in harmony with the conclusions from Bhabha's theory of ionization by mesotrons as regards the story of variation from element to element.

[1] W. F. G. Swann, Rev. Mod. Phys. 11, 242 (1939).

**3. The Energy Loss of Electrons in Carbon.** H. R. CRANE, N. L. OLESON AND K. T. CHAO, *University of Michigan.*—Experimental data on the energy loss of high

energy particles in solid materials have recently assumed an increased importance because of the theory put forward by Fermi,[1] concerning their bearing upon the decay of the mesotron. A re-evaluation of the data already existing, as well as a report upon new measurements, will be given. The new measurements were made with a cloud chamber, using electrons of 10 Mev energy. The electrons passed perpendicularly through a plate of carbon weighing 0.82 g/cm², in a magnetic field of 3480 gauss. Two hundred and fifty-five electrons gave an average energy loss of 1.86 Mev/g/cm². After subtracting the expected radiative loss, this becomes 1.73 Mev/g/cm², which is the loss due to collisions alone. The Bloch formula gives 1.93 Mev/g/cm². The Fermi correction for the effect of the dielectric constant would reduce the theoretical value to about 1.4 Mev/g/cm². If a correction were applied for the path length in the absorber, it would probably not be more than 1 percent, because the observed average angle of scattering (in the projection) was only 6 degrees. Clearly it is difficult to say whether or not the experiments support the Fermi theory, since the effect we are seeking to observe is not large compared to the experimental uncertainties.

[1] E. Fermi, Phys. Rev. **56**, 1242 (1939).

**4. The Relative Meson Stopping Power of Lead and Water.** MARTIN A. POMERANTZ AND THOMAS H. JOHNSON, *Bartol Research Foundation of the Franklin Institute.*—The accurate interpretation of the difference in the absorption of mesons in air and lead presupposes a knowledge of the relative meson stopping powers of these substances. From an experimental comparison of the intensity of the hard component of cosmic radiation under 8.9 meters of water with the intensity under a lead shield, it has been possible to determine directly that 890 g/cm² of water has the same effect in absorbing mesons with energies of about a billion ev as 1547 g/cm² of lead. Thus, the ratio of the relative stopping powers per gram per square centimeter, $S_{H_2O}/S_{Pb}$, is equal to $1.72 \pm 0.22$. The theoretical value of $S_{H_2O}/S_{Pb}$ calculated with the theory of Bethe and Bloch equals 1.82, in agreement with the experimental result. It is concluded that the theory of Bethe and Bloch, and not a mass absorption law, affords a suitable method of determining what thickness of one absorber is equivalent in stopping power for mesons to a given thickness of any other.

**5. The Production of Neutrons by Cosmic-Ray Showers.** S. A. KORFF, *Bartol Research Foundation of the Franklin Institute.*—The production of neutrons in cosmic-ray showers has been investigated by the coincidence counting method. Coincidences were recorded between the discharges of a $BF_3$-filled neutron-counter[1] and a Ramsey-type shower tray.[2] The latter was so adjusted that the simultaneous discharge of any two or more counters, out of an array of 25 arranged horizontally, was necessary in order to record as a coincidence. A slab of lead 5 cm thick was used to produce showers. The neutron counter was enclosed in 7 cm paraffin and placed above the lead. It was found that accidentals and spurious discharges accounted for less than 5 percent of the observed coincidence rate. The counting rate of the neutron-shower coincidences indicated that, out of all showers of 2 or more rays, one in every $100 \pm 50$ was accompanied by the production of a neutron. This is approximately the same rate of production as that of protons observed in cloud chambers.[3, 4] A preliminary measurement with the shower tray adjusted so that four counters had to discharge in order for a coincidence to be recorded showed a decrease in the rate of neutron-shower coincidences less than proportional to that between the two- to four-ray shower counting rates.

[1] S. A. Korff and W. E. Danforth, Phys. Rev. **55**, 980 (1939).
[2] W. E. Ramsey, to appear shortly.
[3] G. L. Locher, Phys. Rev. **44**, 779 (1933); J. Frank. Inst. **224**, 555 (1937).
[4] C. D. Anderson and S. H. Neddermeyer, Phys. Rev. **50**, 263 (1936).

**6. The Contribution of Showers to the Coincidences Recorded at High Elevations.** J. G. BARRY AND T. H. JOHNSON, *Bartol Research Foundation of the Franklin Institute.*—Flights have been made up to 47 cm $H_2O$ from Swarthmore to determine the contribution of air showers and showers arising in the batteries to the coincidences of three counters arranged as those used for measuring the east-west asymmetry of the soft component of the cosmic rays in Panama in 1939. If a large fraction of the counts recorded on the Panama flights had been produced by showers, the east-west symmetry found there would not necessarily have indicated symmetry of the primary particles and an equality of the numbers of primary positives and negatives. The test flights, however, have shown that at least 95 percent of the coincidences recorded were produced by single cosmic rays from the direction of the counter train and only about five percent of the counts can be attributed to showers and accidental coincidences. Thus there seems to be no way of avoiding our former conclusion that the primary electrons of the soft component are symmetrically distributed and therefore cannot be the primary particles which produce the strongly asymmetric mesons of the hard component. The latter therefore must have been produced by some other type of positively charged primary particles, presumably protons.

**7. On the Theory of Meson Decay.** L. W. NORDHEIM, *Duke University*, AND H. A. BETHE, *Cornell University.*—The theory of the meson decay has been re-examined in view of the disagreement between the results of various authors. A simultaneous theory of radioactive $\beta$-decay and the spontaneous meson disintegration is obtained automatically[1] by the one simple assumption of existence of a coupling between mesons and the electron-neutrino field in strict analogy to the coupling between mesons and the proton-neutron field. The formalism of the theory can be considerably simplified by using the classical (unquantized) form of the meson field equations. However, it is not possible on the basis of the present meson theory (vector field) to obtain a numerical fit for both effects. The meson lifetime cannot be made larger than about $10^{-8}$ sec. if the available constants are adjusted so as to give the correct strength of nuclear forces and the correct time constant of radioactive decay. Our results agree essentially with those of Yukawa and Sakata.[2]

[1] In contrast to the view expressed by R. Serber, Phys. Rev. **56**, 1065 (1939).
[2] H. Yukawa and S. Sakata, Nature **143**, 761 (1939).

**8. Meson Pair Theory of Nuclear Forces.** R. E. MARSHAK, *University of Rochester.*—The interpretation[1] of the proton-proton scattering experiments on the basis of Bethe's[2] "neutral" meson theory leads to a range of nuclear forces $\approx \frac{1}{2}\hbar/\mu c$ ($\mu$ is meson mass). This implies a mass for the field particle equal to about twice the mass of the cosmic-ray meson. It has also been found[2] that a meson theory of nuclear forces involving the emission and absorption of single charged particles, obeying Bose statistics, does not give the right sign of the quadrupole moment of the deuteron. In view of these difficulties and the fact that the "single" meson theory cannot correctly explain the $\beta$-decay anyway, we have investigated the consequences of a meson "pair" theory of nuclear forces. The mesons are assumed to be identical with electrons in every respect ("hole" theory, Fermi statistics, etc.) except that their rest mass is taken equal to the cosmic-ray meson mass. A tensor interaction between the heavy particles and the meson pair field (just as in Bethe's "neutral" theory) can alone account for the spin dependence of nuclear forces and the positive quadrupole moment of the deuteron. It is interesting that a pseudo-vector interaction gives the wrong sign of the quadrupole moment. The interaction energy between two heavy particles behaves at large distances, $r$ as $e^{-2\kappa r}$, $\kappa \approx \mu c/\hbar$, so that the range is effectively one-half the "single" meson range, and is directly connected with the rest mass of the meson pair field (in contrast with the electron pair theory[3]). At small $r$, the potential goes as $1/r^5$ so that one has to cut off in the same way as in the original electron-neutrino theory. The advantage of our theory over a heavier "neutral" theory is that it deals with particles which can be identified with the cosmic-ray mesons.

[1] Hoisington, Share and Breit, Phys. Rev. **56**, 884 (1939).
[2] H. A. Bethe, Phys. Rev. **55**, 1261 (1939).
[3] G. Gamow and E. Teller, Phys. Rev. **51**, 289 (1937).

**9. Electric Quadrupole Moment of Deuteron.** A. NORDSIECK, *Columbia University.*—K. R. R. Z.[1] have discovered in HD and $D_2$ an interaction ascribable to an electric quadrupole moment of D. The energy due to such a moment is proportional to the moment and to the electric field gradient at the deuteron. This field gradient has been calculated with a simple but rather accurate electron wave function. We take as measure of the electric quadrupole moment $e(3z^2-r^2)_{Av} \equiv eQ$, where $z$ and $r$ are coordinates of the proton in the deuteron, relative to the center of mass, and the average is taken over the state with the greatest $z$ component of the spin. The field gradient points inward along the molecular axis and is $e[2/R^3 - \int d\tau\rho(3\cos^2\theta - 1)/r^3]_{Av} \equiv 2eq$, averaged over the molecular vibration. $R$ is the internuclear distance, $\rho$ the electron density, $r$ the distance from the D nucleus, and $\theta$ the angle $r$ makes with the molecular axis. The author finds $q = 1.193 \times 10^{24}$ cm$^{-3}$ and estimates that this value is trustworthy to within $\pm 2$ percent. K. R. R. Z. have kindly furnished their unpublished accurate value of the term difference concerned: $\frac{1}{2}e^2qQ = (87.5$ oersteds$)\cdot($magnetic moment of D). Whence $Q = +2.74 \times 10^{-27}$ cm$^2$, with the same estimated uncertainty as for $q$. Details of the calculations will appear shortly.

[1] J. M. B. Kellogg, I. I. Rabi, N. F. Ramsey, Jr., and J. R. Zacharias, Phys. Rev. **55**, 318(L) (1939).

**10. On the Determination of the Nuclear Quadrupole Moments by the Molecular Beam Method.** EDWARD TELLER, *The George Washington University.*—In order to determine nuclear quadrupole moments by the molecular beam method one has to know the anisotropic part of the inhomogeneity of electric fields near the nuclei. For diatomic molecules this quantity may be obtained from experiments on scattering of light. If $\rho$ is the depolarization factor for polarized incident light scattered at right angle one has

$$Z_1 e\left(\frac{\partial^2\varphi}{\partial x^2} - \frac{\partial^2\varphi}{\partial y^2}\right)_1 + Z_2 e\left(\frac{\partial^2\varphi}{\partial x^2} - \frac{\partial^2\varphi}{\partial y^2}\right)_2 = \pm\left[\frac{m\omega^2}{2}\sqrt{5\rho}\right]_{\omega\to\infty}.$$

Here $Z_1 e$ and $Z_2 e$ are the nuclear charges, $\varphi$ is the electric potential, $x$ is parallel to the molecular axis, the factors of $Z_1 e$ and $Z_2 e$ are taken at the positions of the respective nuclei, $m$ is the electronic mass and $\omega$ is $2\pi$ times the frequency of the scattered light. The quantity appearing on the right-hand side is a limiting value taken at high frequencies. It will be difficult to obtain the necessary experimental data since depolarization measurements in the far ultraviolet are involved.

**11. On Energy Loss in the Theory of Multiple Scattering.** M. E. ROSE,* *Yale University.*—In the theoretical investigation of the pre-diffusion stage of multiple scattering it is customary to neglect one or more of the following: (1) large angle single scattering, (2) fluctuation in path length and the difference between path length and foil thickness, (3) back scattering and (4) energy loss. It has been shown[1] that the neglection (1) overestimates the multiple scattering; but a more accurate treatment of the other effects would increase the calculated scattering.[2] In the realm of applicability of the prediffusion treatment the contribution of all the effects is of the same order of magnitude and, for consistency, at least first-order corrections should be considered in each case. In addition to the contribution of the inelastic collisions to the scattering, the slowing down of the electrons will result in a larger number of elastic collisions, or a decrease in the "transport mean free path"[2] corresponding to a more rapid loss of forward momentum. The angular distribution then becomes broader and the most probable angle greater (approach to diffusion). The effect of energy loss will be most important for light elements and slow particles. For the scattering of 1-Mev electrons in 0.025 cm Al foils[3] the most probable angle of deflection is increased by 10 percent.

* Sterling Fellow.
[1] S. Goudsmit and J. L. Saunderson, Phys. Rev. **57**, 24 (1940).
[2] H. A. Bethe, M. E. Rose and L. P. Smith, Proc. Am. Phil. Soc. **78**, 573 (1938).
[3] M. M. Slawsky and H. R. Crane, Phys. Rev. **56**, 1203 (1939).

**12. Structure of the *L* Absorption of Sodium Metal and Its Halides.** H. M. O'BRYAN, *Georgetown University.*—The structure of the soft x-ray absorption of thin films of sodium metal, NaF, NaCl, NaBr, and NaI has been

photographed in the region between 250A and 430A with a plane grating vacuum spectrograph having a resolving power of 0.1 electron volt. The structure observed in these solids is much narrower and more complicated than found for the same substances in the absorption of ordinary x-rays. Sodium metal has a sharp edge at 405A and relatively faint structure at shorter wave-lengths. The sodium halides have narrow intense absorption "lines" beginning near 380A and extending toward shorter wave-lengths. These absorption "lines" of the crystals have widths of about 0.5 ev and almost the same wave-lengths as the emission of NaII in the vacuum spark. Continuous absorption in the halides starts near 45 ev which is not far from the ionization potential of the gaseous sodium ion at 47 ev. This similarity between the energy levels of the sodium ion in the solid lattice and in the gaseous state indicates a highly ionic character of the alkali halides and surprisingly little broadening and displacement in the solid state.

**13. Progress Report on Radioactive Standards.*** CLARK GOODMAN AND ROBLEY D. EVANS, *Massachusetts Institute of Technology.*—An international intercalibration among laboratories engaged in the measurement of feeble radioactivities[1] is being carried forward under the direction of the Committee on Standards of Radioactivity of the National Research Council. Twelve rock samples, representing widely different lithologic types and containing a broad range of radioactivities, have been prepared as standard samples by the National Bureau of Standards. Beta- and gamma-ray standards and dilute radium and thorium standards are also being prepared. Sixty radioactivity measurements have been completed at the Massachusetts Institute of Technology as part of the cooperative certification of these standards. These preliminary results indicate that (1) emanating power, (2) degree of fusibility, (3) contamination, and (4) inhomogeneity must be considered in the application of the rock standards. Three granite samples showed emanating powers of 40, 10 and 0 percent. Measurement after storage in sealed tubes[2] accurately corrects for this effect. Unusually high temperatures must be used in the direct-fusion of feldspathic rocks Redistillation and recrystallization eliminate radioactive contaminations in distilled water, C.P. nitric and hydrochloric acids and C.P. barium compounds. Reagent alcohol and C.P. sodium carbonate are generally quite free from activity. Repeat measurements on separate portions of the same 100-gram lot of ground rock sample show inhomogeneities up to 30 percent, which emphasize the need of several determinations for calibration purposes.

* Supported in part by the American Philosophical Society.
[1] Evans and Goodman, Phys. Rev. **53**, 916(A) (1938).
[2] Evans, Rev. Sci. Inst. **6**, 101 (1935).

## FRIDAY AFTERNOON AT 2:00 O'CLOCK

## Room 329

(For simultaneous session of the Optical Society, Room 428, see pages 24–26)

**14. Self-Consistent Field for Doubly Ionized Magnesium.** W. JACQUE YOST, *Brown University.* (*Introduced by R. B. Lindsay.*)—A self-consistent field without exchange has been calculated for MgIII in the normal state as a preliminary step to the calculation of the field with exchange for the same configuration. All equations were integrated numerically with the aid of a calculating machine. Only three approximations were necessary throughout to obtain the usual standard of self-consistency, i.e., $\pm 0.001$ in the final $Z(nl|r)$. Interpolation from these results provides a good initial estimate for the equations including exchange. A comparison between the usual method of calculation and that in which the $Y_k$'s are obtained simultaneously with the solution was made, following the suggestion of Hartree,[1] both for the equations with exchange and those without. It has been found that the simultaneous solution for the $Y_k$'s, in both cases, requires a greater amount of computation and does not sufficiently aid the convergence to be worth using. It has been found that the $Y_k$'s can be calculated with sufficient accuracy by a double quadrature instead of by the differential equations suggested by Hartree.[1] The calculation of the field with exchange is now in progress and should prove useful in investigating the metallic state of Mg.

[1] Proc. Roy. Soc. **150**, 22 (1935).

**15. Van der Waals Potentials at the Surface of Metals.** W. G. POLLARD, *University of Tennessee,* AND H. MARGENAU, *Institute for Advanced Study, Princeton.*—A simplified model of a metal, consisting of a barrier behind which electrons are trapped in a region of constant potential, is used for calculating the van der Waals force between a metal and an adsorbed atom. The result shows the potential to vary as $1/R^3$ for large distances of separation $R$, more rapidly for small $R$. The numerical values are much smaller than those obtained by Lennard-Jones[1] using an image force model. This discrepancy arises, aside from imperfections of the present model, from the fact that the instantaneous dipoles induced in the metal are not exactly in phase with the motion of the atomic electrons, an assumption implied in the image force model. The formula obtained is applied to various systems adsorbed to Na and Cu surfaces. Fair agreement is found between theory and experimental heats of low temperature adsorption, although relevant instances of comparison are not numerous. While the image-force theory results in the same formula for the attraction between a given atom and all conductors, the present analysis introduces the constants of the metal.

[1] Lennard-Jones, Trans. Faraday Soc. **28**, 334 (1932).

**16. Energy Levels in Solid Chrome Alum.** R. FINKELSTEIN AND J. H. VAN VLECK, *Harvard University.*—It is shown that Spedding and Nutting's data on the Zeeman effect of the lines of chrome alum in the vicinity of 15,000 $cm^{-1}$ are intelligible if they are inter-system combinations. Calculations are made to examine whether the corresponding locations of the energy levels are reasonable theoretically. The positions of the states for the free chromic ion are known from direct or extrapolated spectroscopic data, and their displacements in the solid alum are calculated under the assumption that the inter-atomic forces are equivalent to a crystalline potential $D(x^4+y^4+z^4)$ with Schlapp and Penney's value of $D$. The classification of levels in the solid shows little resemblance to that in the gas. For the doublet states it is essential to include matrix elements nondiagonal in the quantum number $L$, which are so powerful that $L$ loses all meaning. It is estimated that there are inter-system combinations of roughly the wave-length observed by Spedding and Nutting. The nondiagonal elements in $L$ are unimportant for the ground level and other states of maximum multiplicity (quartets in chromium). Computations of magnetic susceptibilities of salts of the iron group made on the assumption that $L$ is a good quantum number can hence be regarded as adequate.

**17. The Local Field in Polarized Dielectrics.** GEORGE JAFFÉ, *Louisiana State University.*—A new deduction for the Lorentz force is given by considering at first such molecules as have their nearest neighbor at a given distance, summing over all dipoles in the field and finally averaging. The Lorentz formula is shown to hold, under very general statistical assumptions, for the mean value of the force. The distribution law of the local field is then deduced for constant dipoles of moment $\mu$ by a process of successive approximations with the aid of a probability theorem of Markoff-Gans. To a first approximation the local field becomes isotropic for weak external fields; its average value is $\bar{R}=16\pi n\mu/(27)^{\frac{1}{2}}$, i.e., more than twice the maximum value of the Lorentz force obtainable with a given dipole density $n$. A second approximation shows the saturation to be dependent on two dimensionless variables $f=E\mu/kT$ ($E$=intensity of the field) and $p_m=4\pi n\mu^2/3kT$. To avoid the difficulties connected with the Clausius-Mosotti formula an influence of the shape of the molecules is suggested (in agreement with Wiener). A modified C-M formula is deduced under this assumption and compared with experimental evidence.

**18. On the Theory of Dielectric Breakdown in Alkali Halide Crystals.** FREDERICK SEITZ AND J. B. SAMPSON, *University of Pennsylvania.*—Von Hippel's theory of ionization breakdown has been applied with different assumptions by Fröhlich and by Seeger and Teller. They obtain the correct order of magnitude of the breakdown field but the wrong temperature dependence. For this reason Franz has suggested that thermal and field ionizations of the normal ions play a role. The present investigation attempts (*a*) to analyze the condition for breakdown more closely and (*b*) to account for the temperature dependence along lines different from those followed by Franz. In connection with (*a*) it is suggested that the accurate criterion is that an electron produce an ion pair or its equivalent, namely an exciton that later disintegrates, in $10^{-9}$ sec. or less. This seems to be more nearly in agreement with Fröhlich's criterion than Seeger and Teller's. In connection with (*b*) it is pointed out that unless the excitons which are produced as a result of the primary excitation process are broken up by the field by field-emitted electrons from the cathode or by temperature there can be no breakdown. It is suggested that the breakdown field is determined at low temperature by the condition that the excitons are decomposed by the field. The observed peak in breakdown voltage in intermediate range arises from competition of three processes affecting excitons: thermal deexcitation, thermal ionization and field ionization. At high temperatures temperature ionization should be rapid enough to lead to the temperature dependence predicated by Fröhlich.

**19. Equation of State and Thermoelastic Properties of the Solid.** H. F. LUDLOFF, *Cornell University.*—Two thermodynamical identities are given which correlate the different thermal and elastic parameters of a solid. In these relations those terms which are not amenable to direct measurements are successively determined by an equation of state for the solid which is derived on the basis of quantum-theoretical considerations. In this way one obtains: (1) A relation between the temperature variation of an elastic parameter and its volume variation produced by external (e.g., hydrostatic) pressures. (2) A relation between the temperature variation of an elastic parameter and the thermal expansion coefficient. (3) The general temperature law which the elastic parameters of solids must obey: at low temperatures a $T^4$-law (this allows extrapolations of the parameters to the abs. zero); at high temperatures a $T$-law. Both laws agree very well with the modern measurements. From these relations a method is derived which allows a numerical transformation of the measurements of the thermal expansion coefficient into the temperature curve of an elastic parameter up to the melting point. Some data on the behavior of thermal and elastic parameters near phase-transition points are discussed.

**20. Torsional Vibrations of Crystalline Cylinders.** WILLIAM FULLER BROWN, JR., *Princeton University.*—The calculation of elastic constants of crystals from observed vibration frequencies of cylinders is complicated by coupling between torsion and bending. Experimentally the torsional frequencies have been found to be determined by the rigidity for pure torsion (no bending) rather than for free torsion (no bending moments).[1] A theoretical analysis leads to the following results. A torsional frequency $\nu$ interacts chiefly with the flexural frequency $f$ for which the number of moment nodes is the same. For long specimens $\nu^2 \gg f^2$; then the frequencies are given approximately by the formulas for uncoupled modes, if the constants used are the rigidity for pure torsion and Young's modulus for free bending. For short specimens $f^2 \gg \nu^2$; then the constants for pure bending and for free torsion must

be used. Other $\nu, f$ pairs interact only if the number of moment nodes is either even for both or odd for both, and then only weakly unless very close together. For sodium at 80°K in a particularly unfavorable orientation, a rigorous calculation shows that the pure torsion formula is correct to 5 percent for the fundamental if the specimen length exceeds 2.2 cm.

[1] S. L. Quimby and S. Siegel, Phys. Rev. **54**, 293 (1938).

**21. The Nature of the Lambda-Point Transition in Ammonium Chloride.** A. W. LAWSON, *Columbia University.*—Measurements have been made on the temperature variation of the isothermal Young's modulus and the coefficient of thermal expansion of pressed specimens of ammonium chloride in the neighborhood of the lambda-point transition at 242.8°K. It is found that a large difference exists between the recently reported[1] values of the adiabatic compressibility and those of the isothermal compressibility in the immediate vicinity of the critical temperature. The data in conjunction with the known[2] temperature variation of the specific heat at constant pressure permit the evaluation of the temperature variation of the specific heat at constant volume, from which it is concluded that the transformation is not to be associated, as previously suggested by Pauling,[3] with the onset of almost free rotation of the ammonium radicals in the crystal lattice.

[1] Lawson and Scheib, Phys. Rev. **55**, 1268 (1939).
[2] Simon *et al.*, Zeits. f. physik. Chemie **A129**, 339 (1927).
[3] Pauling, Phys. Rev. **36**, 430 (1930).

**22. X-Ray Study of the $A_3$ Point of Pure Iron Using the Geiger-Mueller Counter.** ALTON P. WANGSGARD, *Pennsylvania State College. (Introduced by Wheeler P. Davey.)*—A new technique of observing crystal phase changes has been developed and applied with success to the $A_3$ phase change of iron. A Geiger-Mueller counter is used with balanced ZrO and $Sr(NO_3)_2$ filters. The $Ac_3$ point of iron has been found to be 910.5°±0.6°C in pure dry hydrogen or helium and evidence has been cited to show that the $Ar_3$ point is very probably between 2° and 2½°C below the $Ac_3$ even for infinitely slow rates of cooling. These data are in agreement with those of Wells, Ackley and Mehl.[1] It is found that the body-centered and face-centered crystals may coexist over a temperature range of approximately 2½°C, with some sort of equilibrium between them. This is in accord with the hydrogen diffusion data of Ham[2] and his co-workers. It is found that crystals will occasionally disintegrate and reform rapidly in these temperature regions and it is suggested that the atoms have a greater mobility near the $Ac_3$ and $Ar_3$ points. The apparent depression of 4°C (due to different solubility of hydrogen in the two phases), as set forth by Ham,[2] has not been found.

[1] Wells, Ackley and Mehl, Tran. A.S.M. **24**, 46 (1936).
[2] C. B. Post, R. E. Lake and W. R. Ham, Trans. Am. Soc. Metals **27**, 530 (1939).

**23. Crystal Models for Close-Packed Systems.** R. B. NELSON AND D. B. LANGMUIR, *RCA Manufacturing Company, Inc.*—A crystal model in the form of a box so constructed that spheres poured into it automatically take up positions in a given three-dimensional lattice is a convenient aid for studying some types of problems of the solid state. Martin[1] has described such a model for the body-centered cube. His device is somewhat laborious to build as the walls must be notched in a special manner. It is possible to make such models for face-centered, body-centered and simple cubic lattices with smooth plane walls if the angles between the edges of the box are properly chosen. The edges should have the relative directions of the lines in the desired lattice along which atoms are close-packed. The walls of the box then correspond to the most closely-packed planes in the particular structure involved. The close-packed directions and planes in the various systems are, respectively: simple cubic, (100) axes, (100) (cubic) planes; face-centered cubic, (110) axes, (111) and (100) (octahedral and cubic) planes; body-centered cubic, (111) axes, (110) (dodecahedral) planes. In the hexagonal system all close-packed directions lie parallel to the basal plane, and the box model degenerates into a plane. This difficulty may be avoided by milling grooves into faces perpendicular to the base. The diamond, and probably also all structures other than the four mentioned, have no close-packed directions, and cannot be represented by models of this type.

[1] S. T. Martin, Phys. Rev. **56**, 947–959 (1939).

**24. On the Theory of Diffusion in Substitutional Alloys.** H. B. HUNTINGTON AND FREDERICK SEITZ, *University of Pennsylvania.*—The present work has been undertaken in an attempt to decide between the vacancy and interstitial mechanisms of diffusion in the case of self diffusion in copper. The experimental activation energy, as measured by Steigman, Shockley and Nix, is 2.6 ev. The energy required to take an atom from the surface to an interstitial site is computed in the following two steps: (*a*) the ion core is taken to the interstitial site and its valence electron is spread uniformly throughout the lattice; (*b*) the polarization of the electron gas by the interstitial ion is included. The greatest uncertainty in computing these energies lies in incomplete knowledge of the ion core repulsion, which we estimated from elastic data. In approximation (*a*) the activation energy is 8.7 ev. The polarization energy is about 3 ev, which reduces the interstitial activation energy to approximately 5.7 ev. A preliminary computation of the activation energy for vacancy diffusion, carried out along similar lines, leads to a value of 4 ev, and indicates a preference for this mechanism of diffusion. These results, however, are strongly dependent upon the ion core repulsion function used and may require revision.

**25. An Electron Diffraction Examination of Electrolytically Polished Surfaces.** H. R. NELSON, *Battelle Memorial Institute.*—A highly polished or burnished metal surface usually gives a diffuse-ring electron diffraction pattern which some investigators believe is due to a layer of amorphous metal called the Beilby layer. Iron, aluminum and stainless steel surfaces have been polished by an electrolytic method in which polishing is effected by the dissolution of metal from the high spots when the specimen is made the anode in a suitable electrolyte. Although such a process cannot produce a layer of amorphous metal, it was

found that the electron diffraction patterns from many electrolytically polished surfaces are identical with those from the same surfaces mechanically polished. Surfaces which were not well polished as indicated by visible grain boundaries gave patterns of spots elongated by refraction at the flat surfaces of single grains. More highly polished surfaces showing no visible grain structure gave the diffuse-ring pattern with only occasional faint spots. Electrolytically polished copper always gave a pattern due to $Cu_2O$. It is believed that a thin film, probably an oxide, covers the surface of electrolytically polished surfaces and gives rise to the diffuse-ring pattern.

## SATURDAY MORNING AT 10:00 O'CLOCK

## Room 401

(For simultaneous session of the Optical Society, Room 428, see pages 26–27)

**26. New High-Sensitivity Galvanometer.** C. HAWLEY CARTWRIGHT, *Massachusetts Institute of Technology.*—The natural limit of a moving coil galvanometer for measuring current or for determining the e.m.f. in a circuit is about 40 percent that of an ideal device.[1] A volt-sensitive galvanometer was constructed which was sufficiently stable for the natural limit to be easily attained, using only optical amplification.[2] The design combines features in the Zernike and Moll galvanometers. For high sensitivity, an Alnico magnet was used, the coil was wound with No. 46 wire, and the period was 10 sec. For stability, the moving system was kept taut between quartz fibers and mechanically balanced so that it was relatively insensitive to level and vibrations. The system was also balanced magnetically so that the effects due to magnetic impurities were avoided.

[1] C. H. Cartwright, Rev. Sci. Inst. 11, 25 and 31 (1940).
[2] M. Czerny, Zeits. f. Physik 90, 468 (1934).

**27. The Three-Crystal Method of Quartz Resonator Measurement.** KARL S. VAN DYKE AND ALAN M. THORNDIKE, *Wesleyan University.*—The present report continues the investigation of the properties of highly selective quartz resonators on which the senior author has reported in the past. The former methods have included decay curve measurements and resonance curve plotting by means of a current meter. The present method uses an impedance bridge. The impedance of the crystal at various frequencies near the peak of its resonance curve is measured with a radiofrequency bridge. By a precise determination of frequency differences from a constant standard of reference the resonance curve is accurately determined. The $L$, $C$, and $R$ and $C_1$ of the crystal's equivalent network are computed, as well as the piezoelectric constant and the $Q$ of the resonator. The method used employs three crystals of nearly identical frequency. One of these serves as driving oscillator, another as the resonator under test, the third as a comparison standard of frequency. Slow beats between this latter and the driver establish the frequency of the current supplied to the bridge. This frequency is varied through the resonance range of the crystal under study by circuit adjustment of the driving oscillator. For the continued study of resonator properties, driver, reference oscillator, mixer and beat counter circuits, as well as the bridge and a detector of extreme sensitivity, have been incorporated in a unit assembly.

**28. Automatic Cathode-Ray Oscillographs for the Recording of Lightning Currents.** J. W. FLOWERS, *General Electric Company.*—Two oscillographs installed below the roof of the Empire State Building and connected to a shunt inserted between the lightning rod and building frame have given current records in strokes during 1938 and 1939. An RCA-908 tube with 1200 volts excitation gives a continuous record for a time of the order of one second upon a film drum of about 30 inches in diameter. Deflection is produced normal to rotation which requires slightly less than one second and serves as the beam sweep. For highest resolution in time, a special tube with 15 kv excitation records high speed oscillograms on a similar drum. During a stroke discharges of sufficient magnitudes and rates are recorded as individual oscillograms which are separated by drum rotation. Nonlinear sweep is produced automatically on the tube screen. The first few microseconds are well resolved although the total time of sweep is of the order of 100 microseconds. Circuit design enables repetition of operation in less than 1000 microseconds. At the end of a complete stroke, the film is automatically reset by drum translation. Initiation requires less than one microsecond regardless of stroke polarity and deflection delay is provided.

**29. Field-Enhanced Secondary Electron Emission.** HERBERT NELSON, *RCA Manufacturing Company, Inc.*—In a Letter to the Editor[1] I recently published data in support of the hypothesis that the secondary-electron emission from "oxide film" targets is enhanced by the presence of a positive surface charge in the film. Additional data supporting this hypothesis have now been obtained. An experiment has been performed in which the potential of the oxide film surface with respect to the metal base has been determined as a function of the velocity of the primary electrons impinging on the film. The surface potential was determined by two different methods. It was determined by its "grid effect" on the thermionic electron current from a fine filament mounted close above the film surface, and in a second method by its effect in shifting the break observed in the curve obtained by plotting the secondary current from the film surface to a collector as a function of low accelerating and retarding potentials applied to the collector. The results obtained may be summarized as follows: (1) The film

surface is negative with respect to the base metal at low primary electron velocities and becomes positive at an electron velocity somewhat lower than that at which the secondary to primary current ratio becomes greater than one. (2) The rate of change of surface potential with primary electron velocity is most rapid in the region where it changes from a negative to a positive value. (3) The relation between the net flow of current through the film and the voltage across the film has been found to be nonohmic in character.

[1] H. Nelson, Phys. Rev. **55**, 985 (1939).

**30. Production of Resonance Radiation.** CLIFTON G. FOUND AND EDWARD F. HENNELLY, *General Electric Company.*—It is reasonable to assume that the rate $I$ of excitation to the first resonance state ($6\,^3P_1$) in the plasma of a mercury discharge should be given by $I \sim n_a n_e F(T)$ where $n_a$ and $n_e$ are the concentrations of atoms and electrons and $F(T)$ is a function of the electron temperature. The electron temperature has been calculated as a function of $p \cdot a$ ($p$=gas pressure, $a$=tube radius) by means of the plasma equations of Tonks and Langmuir,[1] and the probability of ionization as determined by Nottingham.[2] The function $F(T)$ has been computed for several electron temperatures by numerically integrating Nottingham's[2] excitation function over a Maxwellian distribution of energies. The final values of $I/n_e$ prove to be proportional to $(p/a)^{\frac{1}{2}}$, over a considerable range of pressure and tube radius. Spectroscopic measurements of the intensity of $\lambda$=2537A were made with mercury discharges at pressures from 0.2 to 20 baryes, currents from 0.05 to 5.0 amp. and tube diameters from 2.5 to 5.0 cm. Simultaneously, electric characteristics were obtained from probe measurements. The measured values of $T$ were practically independent of arc current and agree closely with those calculated from the Tonks-Langmuir equations. The measured dependence of intensity of 2537A radiation on the arc parameters was closely the same as the simple theory outlined above predicts for the rate of generation of excited atoms. The results indicate, in addition, that cumulative ionization and cumulative excitation are negligible under these experimental conditions.

[1] Tonks and Langmuir, Phys. Rev. **34**, 876 (1929).
[2] Nottingham, Phys. Rev. **55**, 203 (1939).

**31. Further Electron Impact Study of NO.** HOMER D. HAGSTRUM AND JOHN T. TATE, *University of Minnesota.*—A mass spectrometric study of the dissociation products of NO under electron impact has shown, in good agreement with the work of Hanson,[1] that the process $NO \rightarrow N^+ + O$ occurs at 21.8 volts. In addition to this the appearance potentials of the $N^+$ and $O^-$ ions indicate that the process $NO \rightarrow N^+ + O^-$ occurs at 19.9 volts. These processes admit of an interpretation completely analogous to that previously made for CO.[2,3] These data constitute further evidence that the $O^-$ ion formed in electron impact processes may exist in a very loosely bound excited state. The process $NO \rightarrow N + O^-$ has been studied also. The results, when compared with the work of Hanson,[1] indicate that dissociation products of zero kinetic energy are not formed. The $O^+$ ions from the process $NO \rightarrow N + O^+$ manifest an ion peak shape which is entirely different from any previously observed. Three possible interpretations of this peak will be presented as a part of a more extensive study of ion peak shapes formed in a mass spectrometer. From such an investigation and from the measurement of appearance potentials on the peak information concerning the heat of dissociation of the molecule, the type of potential energy curve involved and its position with respect to that of the ground electronic state may be obtained.

[1] E. E. Hanson, Phys. Rev. **51**, 86 (1937).
[2] W. W. Lozier, Phys. Rev. **46**, 268 (1934).
[3] H. D. Hagstrum and J. T. Tate, Phys. Rev. **55**, 1136(A) (1939).

**32. Dissociation of $NH_3$ by Electron Impact.** MARVIN M. MANN, ANDREW HUSTRULID AND JOHN T. TATE, *University of Minnesota.*—A mass-spectrometric study of the ionization and dissociation of $NH_3$ by electron impact has been made. The ions which have been observed, their appearance potentials, and their relative intensities, are given in the table.

| Ion | Abundance | Appearance Potential (volts) |
|---|---|---|
| $NH_3^+$ | 100 | 10.5 ±0.2 |
| $NH_2^+$ | 78.2 | 15.7 ±0.2 |
| $NH^+$ | 4.5 | 19.5 and 24.0 (±1.0) |
| $N^+$ | 1.7 | 24.3 and 28.2 (±1.0) |
| $H^+$ | 0.7 | 22.8 and 26.5 (±1.0) |
| $NH_3^{++}$ | 0.03 | 42.0 ±3 |

No evidence that any of these ions result from secondary processes has been observed. The value of 10.5 volts for the ionizing potential of ammonia is slightly lower than that of 11.2, reported by Bartlett,[1] and 11.1, reported by Mackay.[2]

[1] Bartlett, Phys. Rev. **33**, 169 (1929).
[2] Mackay, Phys. Rev. **24**, 319 (1924).

**33. Collision Cross Sections of Li Atoms and $Li_2$ Molecules Scattered in He and in A.** PAUL ROSENBERG, *Columbia University.*—The gas-kinetic collision cross sections of Li atoms and $Li_2$ molecules are measured under identical conditions. A beam of neutral Li atoms contains approximately 1 percent of neutral $Li_2$ molecules. To obtain a beam of $Li_2$ molecules, the atoms are deflected completely out of the beam by an inhomogeneous magnetic field which does not appreciably deflect the molecules. The beam, which has a temperature of approximately 956°K, is scattered by a gas which is at room temperature. The scattering gas is confined to a small portion of the length of the beam. Particles of the beam which are scattered through an angle greater than 45 seconds miss the detector. The intensity of the beam is measured as a function of the density of the scattering gas. The table gives the results for two different scattering gases, helium and argon.

| | Effective Collision Cross Section $cm^2 \times 10^{16}$ | Percent Accuracy | Ratio of Cross Section of $Li_2$ Molecule to Cross Section of Li Atom |
|---|---|---|---|
| Li in He | 114.4 | 2.0 | 1.60 |
| $Li_2$ in He | 183.1 | 3.5 | |
| Li in A | 368. | 2.5 | 1.52 |
| $Li_2$ in A | 558. | 5. | |

The ratio of the cross section of the $Li_2$ molecule to the cross section of the Li atom remains sensibly constant

although the cross sections themselves change by a factor greater than 3 when going from He to A. The same phenomenon has been observed[1] for K atoms and $K_2$ molecules.

[1] P. Rosenberg, Phys. Rev. **55**, 1267 (1939).

**34. Theory of Isotope Separation by Thermal Diffusion: The Cylindrical Case.** W. H. FURRY AND R. CLARK JONES, *Harvard University.*—The theory recently developed for the plane case[1] has been extended to cover the cylindrical case. The solution is for a gas whose properties have Maxwellian temperature dependences, and is equally valid for apparatus with small and large ratios of radii, i.e., of the type used by Brewer and Bramley, and by Nier[2] on the one hand, and by Clusius and Dickel on the other. The solution is in closed form, although the final integrals yielding $H$ and $K$ must be found numerically. A solution in series, valid for ratios of radii not far from unity, has also been obtained. The solution for the case $T_2/T_1=2$, $r_1/r_2=1.455$, indicates that the values of $H$, $K$, and $K_d$, as computed by the formulae for the plane case,[1] should be multiplied by the correction factors 1.13, 1.21, and 0.96. These corrections reduce the discrepancy between the theory and the experimental results of Nier[2] from 17 percent to 4.5 percent, if a parasitic remixing of $K_p/K=0.50$ is assumed. The case of $T_2/T_1=6$, $r_1/r_2=79.4$ has also been computed. If, in each of these two cases, the outer radius is adjusted to obtain a maximum $A_d=H/2(K+K_d)$ for the same gas at the same pressure, with the same power input per unit length, the ratios of the $H$'s and of the $A_d$'s are 0.825 and 1.73. Considering $A_dH$ as a measure of efficiency, we find that in this case the hot wire apparatus is 1.43 times as efficient as the concentric tube type.

[1] W. H. Furry, R. Clark Jones and L. Onsager, Phys. Rev. **55**, 1083 (1939).
[2] A. O. Nier, Phys. Rev. **57**, 30 (1940).

**35. Separation of Isotopes by Thermal Diffusion.** LARS ONSAGER, *Yale University.*—The most advantageous operation of the Clusius-Dickel process from any one point of view depends on the choice of $K_C/K_D$=the ratio of convection to diffusion. This ratio varies as $g^2l^6/D^4$, where $l$=linear dimension of the apparatus, $D$=the mean coefficient of diffusion, and $g$=980 cm/sec.$^2$. The choice of $K_C/K_D$ will generally depend on a compromise between the considerations of concentration, output and hold-up, the inconveniences of very large or very small apparatus, and power consumption. The lowest value of $K_C/K_D$ that seems advantageous from any point of view is $\frac{1}{3}$; the upper limit is set by the critical condition for turbulence.

**36. Thermal Separation of Isotopes.** WILLIAM W. WATSON, *Yale University.*—The construction and operation of a multi-stage apparatus for the concentration of $C^{13}$ by the method of thermal diffusion are discussed. The apparatus is built entirely of copper pipe, each unit being based on a $\frac{1}{2}$-inch G.E. calrod heater of 2 meters effective heating length. To increase the efficiency, successive groups of two units have smaller spacing between hot and cold surfaces, and in all units heat losses by conduction at the ends are minimized by use of stainless steel connecters. Tests with methane and with $CH_4$-$N_2$ mixtures show that (1) the convection flow of the gas is lamellar, (2) convective coupling of the bottom of one unit to the top of the next by means of two pipes, one of which is heated, functions well, since two units so coupled have a separation factor approximately the square of that of a single unit, (3) two units produce 2.77 percent $C^{13}$. A 1-meter scrubbing column is placed ahead of the first column, fresh gas is introduced into a coupling pipe at the bottom of the scrubber and gas slightly enriched in $C^{12}$ valved-off at the top. Other details of a six-unit model to produce 20 percent $C^{13}$ are presented.

**37. Carbon Isotopes of Mass Ten and Eleven.** W. H. BARKAS,* E. C. CREUTZ, L. A. DELSASSO, J. G. FOX AND M. G. WHITE, *Princeton University.*—In earlier work in this laboratory[1] the bombardment of boron with high energy protons was found to yield $C^{11}$ from $B^{11}$ by a $(p,n)$ reaction. It has now been observed that a further period of 8.8±0.8 sec. assignable to $C^{10}$ according to the reaction $B^{10}(p,n)C^{10}$ is present when the proton energy exceeds about 5.6 Mev. Other conceivable reactions lead to well-known nuclei, or to $B^9$ by $B^{10}(p,D)B^9$. $B^9$, however, is probably unstable against disintegration into heavy particles.[2] It has been found possible to study the $C^{10}$ activity in the presence of the very intense radiation from $C^{11}$ by absorbing out a large part of the softer radiation from $C^{11}$. Experiments on the absorption of the beta rays of $C^{11}$ in aluminum and the measurement of the upper limit of the spectrum in an expansion chamber indicate that the disintegration energy of $C^{11}$ into $B^{11}$ is less than that formerly obtained.[3] Work on the beta-ray energy of $C^{10}$ is in progress. The carbon isotope of mass ten is of considerable interest as it is the first example to be reported of a nucleus with two more protons than neutrons. The binding energy of $C^{10}$ relative to $Be^{10}$ provides information on the coulomb energy, while its binding energy relative to $B^{10}$, like that of its isobar $Be^{10}$, furnishes data on the spin dependent forces.

* Member, The Institute for Advanced Study, Princeton, New Jersey.
[1] W. H. Barkas, Phys. Rev. **56**, 287 (1939).
[2] H. A. Bethe, Phys. Rev. **54**, 436 (1938).
[3] Fowler, Delsasso and Lauritsen, Phys. Rev. **49**, 561 (1936).

## SATURDAY MORNING AT 10:00 O'CLOCK

## Room 329

(For simultaneous session of the Optical Society, Room 428, see pages 26–27)

**38. New Evidence on Particles of the Light Wave-Length Size.** FELIX EHRENHAFT, formerly at *Vienna University.* (*Introduced by W. L. Severinghaus.*)—The solution of the old unsolved problem of measuring correctly bodies of a diameter of light wave-length size can be reached by shoving together two equally sized spheres under a

microscope using a micromanipulator. The images overlap, thus rendering possible a determination of the true size of those spheres. The velocities of fall of the same spheres have been measured at several increasingly high gas pressures up to a region where the application of Stokes' formula is justified. From that formula a value of the diameter is obtained which equals exactly the one resulting from the above independent method. Another way to treat it is to determine the size of a sphere by the optical method, and then from the velocities of fall its density, which came out exactly equal to that of the macroscopic substance. Those accurate methods are of importance for instance for the author's method of determining the electric charge of a single sphere, and also for new questions arising from photophoresis, the motion of particles under the influence of an intense beam of light. There are several grave difficulties in explaining photophoretic forces as a difference action of pressure of light (Kepler)—light positive—and radiometer (Crookes) forces—light positive or light negative. For highly reflecting silver particles can move toward the light (light negative) and above all because attracting forces of the same order of magnitude were also found in liquids where radiometer forces do not exist.

**39. On the Ratio of $c$, $e$, and $\hbar$.** ALFRED LANDÉ, *Ohio State University.*—The relation between the universal constants $c$, $e$, $\hbar$ is reduced to an eigenvalue problem. Sommerfeld's fine structure constant $\alpha=e^2/c\hbar$ appears as the eigenvalue of an integral equation for $\psi(\Delta r)$ where $\Delta r$ is the Dirac signal radius of an electric particle whose rest signal radius is $a=2e^2/3mc^2$. If $\Delta t$ is the time saved by a light signal (Dirac) then $(c\Delta t)^2-\Delta r^2=-a^2$ is an equation "reciprocal" to Einstein's $(E/c)^2-p^2=b^2$ with $b=mc$. Relativity and quantum theory then lead to an integral equation for the amplitude of finding various values of $p$: $\chi(p)=(\alpha/3\pi)\int\int\chi(p')\exp\{(i/h)[\Delta r(p-p')-\Delta t(E-E')]\}\times dV_\Delta dV_p$, in which, according to Born, $(E/c)^2$ and $(c\Delta t)^2$ are to be replaced by $b^2+p^2$ and by $\Delta r^2-a^2$. The elements $dV$ are invariant volume elements. In the *proper* space of $P_0=\sinh^{-1}(p/b)$ and $D_0=\cosh^{-1}(\Delta r/a)$ the integral equations for $\chi(p)$ and $\psi(\Delta r)$ are identical and can be reduced to the *one-dimensional* equation $\varphi(s)=(2\alpha/3)\int\varphi(s')L(s,s',\alpha)\times ds'$ where $L$ is a real positive symmetric kernel consisting of four Bessel functions $L=K_0(x_1)-K_0(x_2)+K_0(x_3)-K_0(x_4)$ with the arguments $x=(4\alpha/3)\begin{matrix}\cosh\\ \sinh\end{matrix}|\tfrac{1}{2}(s\mp s')|$. The *physical* value of $\alpha$ is presumed to be the smallest eigenvalue of the integral equation. The theory is based on preliminary results of Born and the writer and on Dirac's result that an electric particle has a signal radius.

A. Landé, J. Frank. Inst. **228**, 495 (1939).
M. Born, Proc. Roy. Soc. Edinburgh **49**, 219 (1939).
P. A. M. Dirac, Proc. Roy. Soc. **A167**, 148 (1938).

**40. A High Efficiency Ion Source.** A. T. FINKELSTEIN AND LLOYD P. SMITH, *Cornell University.*—An ion source has been built which is capable of producing intense ionic beams of any material which acquires an appreciable vapor pressure below 2000°C. The ionizing electrons are held in a beam by an axial magnetic field, and are made to oscillate through the region occupied by the gas with energies corresponding to the maximum ionization probability. The ion current produced in this manner is 20 to 40 times that which would be expected from the cathode emission current. The electronic space charge is used to withdraw the ion beam and hold the beam together. Using potentials no greater than 60 volts, hydrogen ion beams of 150 milliamperes and calcium ion beams of 80 milliamperes have been obtained.

**41. Electrostatic Generator for Nuclear Research at M. I. T.** D. L. NORTHRUP, L. C. VAN ATTA, R. J. VAN DE GRAAFF AND J. S. CLARK, *Massachusetts Institute of Technology.*—The electrostatic generator[1] formerly located at Round Hill was transferred in October 1937 to the M. I. T. grounds in Cambridge. The generator is now housed in a welded steel shell with underground rooms for belt machinery and target equipment. The two units of the generator structure are erected with terminals in contact to obtain in effect a single high voltage terminal supported on two insulating columns. The charging belts are located in one column and the accelerating tube in the other. This arrangement with grounded target limits the voltage to 2.5 Mev but greatly facilitates its use and makes possible adequate radiation shielding. Three rubber fabric belts supply currents up to 4 ma. The generator is operated entirely by remote control from a station in the adjoining laboratory building. At this station are located also controls for vacuum and other auxiliary apparatus, and detection equipment for the operation of counters and ionization chambers at the target. The moving and re-erection of the generator structure and the construction of a new charging belt assembly and a remote control system required somewhat less than a year. The reliable performance of the installation has facilitated its application to the acceleration of positive ion and electron beams as described in the following abstract.

[1] Phys. Rev. **49**, 761 (1936).

**42. Progress Report on the High Voltage Production of Positive Ion and Electron Beams.** C. M. VAN ATTA, R. J. VAN DE GRAAFF, L. C. VAN ATTA AND D. L. NORTHRUP, *Massachusetts Institute of Technology.*—An account will be given of the production of beams of positive ions and electrons by means of the generator installation described in the previous abstract and an accelerating tube of the general type described earlier.[1] The tube is mounted axially inside one of the upright cylindrical generator columns which affords the necessary corona shielding. The 23-foot insulating portion of the tube is composed of 52 cylindrical porcelain sections 12 inches in diameter separated by steel diaphragms. Both oil and mercury diffusion pumps have been used in evacuating the tube, the lowest pressure of gas plus vapor ($6\times10^{-7}$ mm Hg) and the cleanest surface conditions being obtained with the mercury pump. With positive ion sources of the capillary diffusion type[2] and with various arrangements for initial focusing, ion beams up to 0.1 ma unanalyzed were obtained on a 5-cm beryllium target. With electrons, beam currents up to 1 ma were obtained on lead and gold targets. For well-focused beams, an electron-gun source and magnetic-field compensation along the tube proved desirable. The x-rays produced at the

target, after some preliminary intensity measurements,[3] are now being applied to the study of indium activation and beryllium disintegration. This research was supported in part by grants from Research Corporation.

[1] Phys. Rev. **51**, 1013 (1937).
[2] E. S. Lamar, E. W. Samson, K. T. Compton, Phys. Rev. **48**, 886 (1935).
[3] Am. J. Roentgenology and Radium Therapy **41**, 633 (1939).

**43. The Measurement of Discharge Characteristics of Geiger-Mueller Counters.** W. E. RAMSEY, *Bartol Research Foundation of the Franklin Institute.* (*Introduced by C. G. Montgomery.*)—An experimental method is presented for determining directly the voltage-time relationship of a counter wire during the interval which begins with the initiation of the discharge and ends when the wire has achieved its maximum negative potential. The procedure allows for the measurement of times ranging from $2.0\times10^{-7}$ second to $1.0\times10^{-4}$ second, and wire potentials between 20 volts and 350 volts. Studies indicate that the relation $V=Q_0/c \log (t/t_0+1)$ represents the data over a considerable range of voltages and times. Here $V$ is the potential of the counter wire, $t$ is the time, $c$ is the capacity of the counter wire system, and $Q_0$ and $t_0$ are parameters determined by counter constants and cylinder voltage. It follows from this relation that the current in the counter is inversely proportional to the time. Discharge characteristics were measured for a series of pressures of an argon-oxygen mixture and in each case a relation of the form indicated was found to represent the data. An argon-alcohol counter, generally spoken of as "self-quenching," has characteristics of the same form. When cylinder voltage is adjusted for equality of pulse size, $t_0 \propto 1/\text{pressure}$.

**44. The Discharge Mechanism of Geiger-Mueller Counters.** C. G. MONTGOMERY AND D. D. MONTGOMERY, *Bartol Research Foundation of the Franklin Institute.*—The measurements of W. E. Ramsey on the variation with time of the potential across a Geiger-Mueller counter (see preceding abstract) are interpreted on the basis of the inductive action of the positive ion space charge moving across the counter. This inductive action, together with the hypothesis that the positive ions may eject electrons when they reach the cathode, furnishes a reasonable explanation of both the fast and slow types of breakdown of counters. This postulated mechanism leads to simple explanations of the quenching of a counter discharge and the necessary conditions for the maintenance of a steady discharge. In particular, it is predicted and verified experimentally that it is possible to operate a counter even when the potential is considerably in excess of that required for a continuous discharge, provided that the capacity of the counter wire is sufficiently reduced. A simple, although indirect, method is described for measuring the breakdown characteristic of a counter which gives results in good agreement with the direct determinations of W. E. Ramsey.

**45. The Interval Selector: A Device for Studying Time Distribution of Pulses.** ARTHUR ROBERTS, *Massachusetts Institute of Technology.*—A vacuum tube device for the study of the distribution in time of voltage pulses from a discharge counter, linear amplifier, etc., or a combination of these has been developed. This apparatus, which we have called an interval selector, records the number of those intervals in any distribution whose duration is equal to or less than $t$, where $t$ is controlled and variable. In the present instrument $t$ may be set at any value from $4\cdot10^{-4}$ to 0.3 second. A simple method for the study of the time distribution of pulses from a discharge counter has thus been made available, and is proving to be of value in detecting spurious effects. A study of the behavior of the various circuits for quenching discharge counters is in progress, as well as a cooperative survey of counters made and used in various laboratories. The resolving times of counters and counter circuits have been measured and compared. The self-quenched alcohol-filled counter has the shortest resolving time, but we have as yet been unable to produce completely satisfactory counters of this type. The interval selector may be used for the measurement of radioactive decay periods of the order of $10^{-4}$ to 1 second.

**46. A Theory on Excitation of Phosphorescence by Cathode Rays.** U. FANO, *Washington Biophysical Institute.* (*Introduced by E. Teller.*)—Phosphorescence produced by cathode rays of from 200 to some thousands of volts converts into light a very small fraction of the electronic energy ($\sim10^{-2}$ to $10^{-3}$), nearly *proportional to the voltage.*[1] On the other hand, $\alpha$- or ultraviolet rays produce phosphorescence with an efficiency nearly 1; the excitation energy released by $\alpha$-particles may diffuse far away ($\sim10^{-5}$ to $10^{-4}$ cm) before being absorbed by phosphorescent atoms.[2] These facts may be explained tentatively as follows: In the interior of a phosphorescent crystal the energy of an excitation may hardly be destroyed except by emission of light by the phosphorescent atoms. The situation may be quite different on the surface of the crystal, where other phenomena may be assumed to destroy the excitation. Under these assumptions the energy of soft cathode rays, which is absorbed within a thin superficial layer, would have a large chance to reach the surface by diffusion and hence to be lost before being converted into light. Theoretical analysis shows that in our case: (*a*) The efficiency, if small, should be approximately equal to the average depth of production of the excitations divided by the range of diffusion of the excitations (for instance: $10^{-7}$ cm/$10^{-4}$ cm $=10^{-3}$); (*b*) the average depth is proportional to the electronic free path for elastic scattering; (*c*) this free path—and hence the efficiency—is *proportional to the initial energy.*

[1] T. B. Brown, J. Opt. Soc. Am. **27**, 186 (1937); W. H. Nottingham, J. App. Phys. **8**, 762 (1937).
[2] For instance, O. Riehl, Ann. d. Physik **29**, 636 (1937).

**47. The Zeeman Effect in Rhodium at 95,000 Gauss.** J. P. MOLNAR AND W. J. HITCHCOCK, *Massachusetts Institute of Technology.*—Using the new 100,000-gauss magnet designed by Bitter,[1] the arc spectrum of rhodium has been photographed in magnetic fields ranging from 70,000 to 95,000 gauss on 180,000 line gratings mounted on a 35-ft. Rowland circle. Lines from both Rh I and Rh II came out very strongly in the photographs. More than 250 resolved patterns and 75 partially resolved patterns of Rh I have been measured and reduced, so that $g$ values are now available for all of the lowest 70 levels. For many levels the

accuracy is high, there being more than twenty transitions to them for which Zeeman patterns have been measured. The Zeeman patterns gave an excellent means of checking and extending Sommer's[2] analysis of the spectrum. For the ground state configuration, $4d^85s$, the $g$ values are very near those given by the Landé formula for $LS$ coupling, if the interaction of the $4d^9$ configuration is taken into account. The $g$ sum rule is found to be valid to a high degree of accuracy for all levels of the $4d^85s$ and $4d^9$ configuration, and for those levels of the excited $4d^85p$ configuration which have been identified.

[1] G. R. Harrison and F. Bitter, Phys. Rev. **57**, 15 (1940).
[2] L. A. Sommer, Zeits. f. Physik **45**, 147 (1927).

**48. A New Optical Method for the Determination of the Principal Stress Sum.** DAVID SINCLAIR, *Columbia University.*—The usual photoelastic method of plane stress analysis affords a direct measurement of the magnitude of the principal stress difference and the directions of the individual principal stresses at every point of a plane model. Various methods[1] have been devised for the direct measurement of the magnitude of the individual principal stresses or the principal stress sum. The present paper[2] describes a transmission method for obtaining the magnitude of the principal stress sum over the whole model at once. Duplicate Bakelite models are placed in a Jamin interferometer and the interference fringes in the loaded models are observed in unpolarized, monochromatic light. By means of a quartz plate a 90° rotation of the light vectors is effected between the two models. This eliminates the affect of the birefringence induced by the stress, so that the fringes observed are fringes of equal model thickness proportional to $P+Q$, the principal stress sum. The method is applied to determine the stress in a mine pillar and a horizontal tunnel under conditions which allow these structures to be represented by statically loaded models.

[1] R. D. Mindlin, J. App. Phys. **10**, 222 (1939); Max M. Frocht, *ibid.* **10**, 248 (1939).
[2] Part of a paper by D. Sinclair and P. B. Bucky, A.I.M.E. Tech. Pub. **1140** (1940).

**49. Raman Spectra of Acetylenes.** FORREST F. CLEVELAND AND M. J. MURRAY, *Armour Institute of Technology.*—Continuing previous work, Raman spectra have been obtained for two monosubstituted and two disubstituted acetylenes: I *Dimethylethynylcarbinol*, II *l-Ethynylcyclohexanol*, III *Di-n-amylacetylene*, and IV *Phenyliodoacetylene*. The region of primary interest was that near 2200 $cm^{-1}$ in which the following frequencies were observed: For I, 2089(3), 2112(10)0.4; for II, 2107(9*b*)0.4; for III, 2231(7)0.5, 2248(2), 2294(4)0.6; for IV, 2172(10). The outstanding result is that *two* frequencies were observed for I, whereas monosubstituted acetylenes previously measured show only *one*. It does not seem possible to account for 2089 by resonance with an overtone or a combination frequency. It is conceivable that the doubling may be due to resonance with the parallel infra-red active frequency, but it seems probable that this frequency would be too low for such interaction. 2089 may be due to some impurity, but this also seems improbable because the liquid had a sharp boiling point and because no likely impurity has a line at this frequency. The three frequencies in III may possibly be the result of resonance interaction with the combination frequencies 970+1271, 1024+1221, and 1024+1271. The observance of only *one* line for IV, rather than the *two* usually observed for disubstituted acetylenes, may be due to the short exposures required by the rapid yellowing when irradiated by Hg 4358A.

**50. The Infra-Red Absorption Spectra of Ammonium Halides.** DUDLEY WILLIAMS, *University of Florida.*—The absorption measurements of Reinkober[1] have been repeated for the purpose of obtaining a check on his results in the case of solid-to-solution variations in the spectra of ammonium compounds. The transmission of fine powders of $NH_4F$, $NH_4Cl$, and $NH_4Br$ was compared with that of aqueous solutions of the same materials. Ammonium iodide was studied only in solution. The absorption curves obtained in the present work were in close agreement with the previously published data. The bands near 5.9$\mu$ and 7.0$\mu$ appear at definitely shorter wave-lengths in the solution spectra, as reported by Reinkober. However, this author's interpretation of the absorption maxima occurring near 3.2$\mu$ seems open to criticism. If the solvent frequencies remain unchanged, it is probable that the ammonium frequencies responsible for the band near 3.2$\mu$ may actually decrease when the salts are dissolved. The present infra-red results are compared with the existing Raman data.

[1] O. Reinkober, Zeits. f. Physik **3**, 1 (1920); **5**, 192 (1921); **35**, 179 (1926).

**51. Sensitization of Photoelectric Surfaces by Electric Discharges in Water Vapor and Atomic Hydrogen.*** J. T. TYKOCINER, JAKOB KUNZ AND L. P. GARNER, *University of Illinois.*—Photoelectric surfaces, especially those obtained by depositing alkali metal vapors, were studied when treated with electric discharges in pure rarified water vapor. It was found that the photoelectric emission increases with the duration of the discharge, reaches a maximum and then decreases rapidly. If during the intermediate stages the cell is evacuated while the alkali surface is bombarded with electrons ejected from a thermionic source and accelerated in an electric field, the photoelectric sensitivity of the surface is not only restored but may exceed the maximum values obtained when subjecting it solely to electric discharges. Potassium photoelectric vacuum cells sensitized by a succession of discharges in water vapor and of thermionic bombardments give a sensitivity about twenty times larger than that of an average Kunz's hydride vacuum cell. The essential condition necessary for effective sensitization is that the discharge show, when viewed through a spectroscope, a predominance in intensity of Balmer lines as compared with the bands which should be hardly visible. This indicates that mainly neutral hydrogen atoms are involved in the process of formation of a sensitive film upon the potassium layer. High sensitivities were also obtained by subjecting alkali surfaces consecutively to atomic hydrogen produced by thermic dissociation of $H_2$ and to thermionic bombardment. However, more stable photosensitive surfaces were obtained by discharges in water vapor. Details of this investigation will be published in a Bulletin of the University of Illinois Engineering Experiment Station.

* To be read by title.

## SATURDAY AFTERNOON AT 2:00 O'CLOCK

### Room 401

(For simultaneous session of the Optical Society, Room 428, see pages 27–28)

**52. Transmission Measurements with Indium Resonance Neutrons (1 ev>$E$>0.5 ev).** H. B. HANSTEIN AND J. R. DUNNING, *Columbia University.*—A systematic study is being made of total cross sections (scattering+capture) of various elements with a parallel beam of indium resonance neutrons ($D$-neutrons). Low energy neutrons are produced in a thin paraffin block exposed to fast neutrons from the proton-Be reaction in the cyclotron. The collimator consists of a boron-cadmium-indium-lined enclosure with diaphragms, so constructed as accurately to define a beam of neutrons 6 cm in diameter, with the detector located 35 cm from the effective neutron source. Samples are placed midway between source and detector, and behind a central collimating diaphragm. Large intensities are obtained so that the activities of very thin indium detectors and indium monitors can be measured with high precision by an ionization chamber-electrometer system. Transmission values are obtained by a filter method employing open beam and sample readings with and without a thin indium filter (0.029 g/cm²). Preliminary results shown in the table for some elements having small capture cross sections indicate only small changes from thermal neutron values. Comparison measurements using cadmium resonance neutrons agree well with boron ionization chamber results.

| ELEMENT | CROSS SECTION $\times 10^{24}$ CM$^{-2}$ |
|---|---|
| C | 4.80 |
| Cu | 7.88 |
| Pb | 9.30 |
| Bi | 8.34 |

**53. Neutron Transmission Studies in Fe-Ni Alloys.** F. C. NIX, *Bell Telephone Laboratories,* AND H. G. BEYER AND J. R. DUNNING, *Columbia University.*—It has been previously[1] shown that the thermal neutron cross section of a 78 atomic percent Ni iron-nickel alloy is not an additive property of the cross sections of the pure components. X-ray[2, 3] and specific heat measurements have shown the existence of order in Fe-Ni alloys. A series of Fe-Ni alloys were produced from high purity electrolytic nickel and carbonyl iron. All were vacuum annealed for a period of four hours at 950°C. One plate of each composition was then drastically quenched in low vapor pressure oil, while the others were annealed in an evacuated tube at 490°C for 30 days and then cooled 10°C per day to 345°C from which temperature they were allowed to cool to room temperature in two days. Microscopic examination of the final specimens displayed an excellent uniformity in crystallite size. The only significant difference between the quenched and annealed alloys for any composition is in the degree of order as the lattice parameter change is trivial. Representing by $p_q$ and $p_a$ the transmission of the quenched and annealed plates, respectively, the values of $p_q-p_a/100p_a$ for various concentrations of Ni are:

TABLE I.

| ATOMIC PERCENT Ni | 100 | 85 | 75 | 55 | 45 | 35 | 0 |
|---|---|---|---|---|---|---|---|
| $\frac{p_q-p_a}{100p_a}$ | −0.9 | 8.5 | 9.3 | 8.2 | 2.5 | 1.3 | −0.6 |

The differences in neutron transmission for corresponding samples should be correlated with change in order.

[1] M. D. Whittaker and H. G. Beyer, Phys. Rev. **55**, 1124 (1939).
[2] P. Leech and C. Sykes, Phil. Mag. **27**, 742 (1939).
[3] S. Kaya and M. Nakayama, Zeits. f. Physik **112**, 420 (1939).

**54. Distribution in Energy of the Fragments from Uranium Fission.** M. H. KANNER AND H. H. BARSCHALL, *Princeton University.*—The energy distribution of the fragments from the fission of U has been measured by the ionization method.[1] Number-ionization curves have been obtained for the single fragments from a thin U layer sputtered on a thick plate and also for simultaneous pairs of fragments due to single fission processes. The latter were found using a thin layer of U sputtered on an Al foil of 1.1 mm air equivalent. The measurements were made in air. The ionization of the fragments was compared with the ionization produced by $\alpha$-particles from ThC′, assuming that the energy for producing an ion-pair is the same in both cases. The single-fragment distribution has two peaks at 64 and 97 Mev. The pair distribution has a single peak at 159 Mev. The latter value is a measure of the kinetic energy released in the process and is in agreement with Henderson's[2] value found by measuring the heat evolved in the fission process. The masses of the recoil nuclei calculated from the energy ratio of the single-fragment peaks are 96 and 143, in the same region as those found from chemical separation of the active fragments.

[1] W. Jentschke and F. Prankl, Naturwiss. **27**, 134 (1939); G. v. Droste, Naturwiss. **27**, 198 (1939); O. Haxel, Zeits. f. Physik **112**, 681 (1939); E. T. Booth, J. R. Dunning and F. G. Slack, Phys. Rev. **55**, 981 (1939).
[2] M. C. Henderson, Phys. Rev. **56**, 703 (1939).

**55. Radioactive Products from Gases Produced in Uranium Fission.** G. N. GLASOE, *Columbia University,* AND J. STEIGMAN, *College of the City of New York.*—Some radioactive products from the gases produced in uranium fission have been studied as to their chemical identity and characteristic half-life periods. Two Rb activities have been observed, one which decays with a 15-min. period into an active Sr with a half-life of the order of 50 days; the other decays with a 17.5-min.[1] period into an apparently inactive end product. The parent of the 15-min. Rb is a gas with a half-life of a few minutes, whereas the other Rb arises from a gas with a period of 175 min. The two products are further distinguished by the fact that absorption in Al shows the emission from the 17.5 min. Rb to have the higher energy. In a similar manner a Cs has been observed which decays with a 33 min.[1] half-life into a Ba which is inactive or of very long or short period with no evidence of the 300-hr. period reported by Hahn and

Strassmann. This is judged by the fact that the logarithmic decay curve is linear over a factor of 1000 in intensity. This Cs is the product of a gas with a period of 18 min.

[1] Hahn and Strassmann, Physik. Zeits. **40**, 673 (1939).

**56. Resonance Capture of Neutrons by Uranium.** HERBERT L. ANDERSON, *Columbia University.*—The resonance capture of neutrons by uranium has been studied using thin detectors of *UX*-free uranyl nitrate and good geometry, which is possible with the intense source of neutrons available from the cyclotron. The correction for the finite thickness of the detector amounted to about 3 percent while that for obliquity was about 2 percent. Using several thicknesses of boron carbide as absorbers the absorption coefficient of boron for the uranium resonance neutrons was found to be $2.0\pm0.5$ cm$^2$/g. This corresponds to a resonance energy of about 5 ev. The cross section at resonance was measured using uranium oxide absorbers. The experimental value, taking into account the phenomenon of self-reversal, turned out to be $5000\times10^{-24}$ cm$^2$. If the single level formula of Breit-Wigner holds and the Doppler width can be neglected compared to the natural width the cross section at resonance should be instead $10{,}000\times10^{-24}$ cm$^2$. The values 5 ev and $5000\times10^{-24}$ cm$^2$ are to be compared with the values 25 ev and $1200\times10^{-24}$ cm$^2$ previously obtained by Meitner, Hahn and Strassmann.[1] The new values are in better agreement with an interpretation based on the single level formula of the capture cross section for thermal neutrons previously reported.[2]

[1] Meitner, Hahn and Strassmann, Zeits. f. Physik **106**, 249 (1937).
[2] Anderson and Fermi, Phys. Rev. **55**, 1106 (1939).

**57. The $p-n$ Reactions in Lithium or Beryllium.** J. E. HILL, *University of Rochester.*—The half-life of $Be^7$ obtained from the reaction $Li^7(p-n)Be^7$ [1, 2] has been found to be $53\pm2$ days, by following a chemically separated sample for over 300 days. The threshold for the reaction $Be^9(p-n)B^9$ has been observed by measuring the slow neutron activity induced in silver plus paraffin and is found to be $1.93\pm0.1$ Mev.[3] This gives the mass difference ($B^9-Be^9$) equal to $1.17\pm0.15$ Mev and makes $B^9$ heavier than $Be^8$ plus a proton or two alpha-particles plus a proton. Consequently $B^9$ cannot be radioactive as reported by Meitner.[4] As a check samples of beryllium, bombarded with up to 18 microampere hours of 6.5-Mev protons, have been placed inside an ionization chamber so that the very soft positrons expected could be observed. A number of periods were observed but none of these had the soft radiation which is required for $B^9$, if it were radioactive.

[1] L. A. DuBridge, Phys. Rev. **55**, 603(A) (1939).
[2] J. E. Hill and G. E. Valley, Phys. Rev. **55**, 678(A) (1939).
[3] Presented at Washington meeting April 27, 1939, but not included in the abstract.
[4] L. Meitner, Naturwiss. **22**, 420 (1934).

**58. Beryllium $(p,n)$ Threshold.** R. O. HAXBY,* W. E. SHOUPP,* W. E. STEPHENS,* AND W. H. WELLS, *Westinghouse Research Laboratories.*—Using high energy protons from the Westinghouse pressure electrostatic generator, we have bombarded beryllium and measured the threshold for the production of neutrons. The neutrons were detected in a boron trifluoride ionization chamber surrounded with paraffin and connected to a linear amplifier and counter. The voltage was calibrated against the 0.862-Mev fluorine $\gamma$-ray resonance using $H_2^+$ and $H_3^+$. The threshold occurs at a proton energy $Ep=2.01\pm0.01$ Mev. This gives $Q_1=1.81\pm0.01$ Mev. Since this is higher than 1.63 Mev, the $Q$ value expected for the noncapture disintegration of beryllium, we are led to the assumption that $B^9$ is formed in the reaction

$$Be^9(p,n)B^9-Q_1.$$

Using this reaction and

$$Be^9(p,d)Be^8+0.557\pm0.006 \text{ Mev}^1$$

and

$$D(\gamma,p)n-2.183\pm0.010 \text{ Mev},^2$$

we calculate

$$B^9-(Be^8+H')=0.184\pm0.015 \text{ Mev}.$$

Hence $B^9$ should disintegrate into heavy particles. Our threshold is lower than that of Hill ($Ep=2.14\pm0.07$ Mev)[3] but confirms and makes more accurate his original suggestion that $B^9$ is formed and disintegrates into heavy particles. We have also bombarded boron carbide with protons and similarly observed the energy threshold for neutron production. Preliminary results give

$$Ep=3.00\pm0.05 \text{ Mev for } B^{11}(pn)C^{11}.$$

* Westinghouse Research Fellow.
[1] Skaggs, Phys. Rev. **56**, 24 (1939).
[2] Rogers and Rogers, Phys. Rev. **55**, 269 (1939); Bethe, Phys. Rev. **53**, 313 (1938); Stetter and Jentschke, Zeits. f. Physik **110**, 214 (1938); Richardson and Emo, Phys. Rev. **53**, 234 (1938).
[3] Reported at Washington meeting of the Physical Society April, 1939. We are indebted to Dr. Hill and Dr. DuBridge for informing us of their experiments.

**59. Deuteron Bombardment of the Separated Isotopes of Neon.** ERNEST POLLARD AND WILLIAM W. WATSON, *Yale University.*—Large samples of neon enriched in both isotopes have been produced by the thermal diffusion method for bombardment with a 2.5-Mev deuteron beam. The separation apparatus consisted of a single two-meter column with a temperature difference of 400°C between surfaces. Starting with $1\frac{1}{2}$ atmospheres pressure, after 20 hours the apparatus was bled at the "light" end down to atmospheric pressure, with the gas continuously circulated convectively between the "heavy" end and a 250-cc flask. The bombardment of $Ne^{20}$ gives rise to stable $Ne^{21}$ while $Ne^{22}$ yields $Ne^{23}$ of a period which we find to be $63\pm5$ seconds. The ratio (2.0) of the activities of $Ne^{23}$ gives the ratio of the amount of $Ne^{22}$ in the samples. The protons of greater than 16-cm range from the two samples were found to fall into three groups, $A$, $B$, and $C$, of energy change values 2.28, 3.33, and 5.08 Mev. Assuming the process $Ne^{20}+D^2\rightarrow Ne^{21}+H^1$, group $C$ gives 20.9999 for the mass of $Ne^{21}$, agreeing with 20.99968 (Bainbridge), and so is due to $Ne^{20}$. The value of the yields are:

| | LIGHT | HEAVY | |
|---|---|---|---|
| $B/A$ | 0.15 | 0.20 | ($\pm0.05$) |
| $C/A$ | 0.44 | 0.45 | ($\pm0.05$) |

Thus $A$ and $C$ have the same origin, $Ne^{20}\rightarrow Ne^{21}$. The $B$ group might be a superposition of groups due to $Ne^{22}$ and $Ne^{20}$ but is probably also due to $Ne^{20}$. The large yield of $Ne^{23}$ indicates a proton group of range less than 16 cm.

**60. Radioactivity Induced in Neon and Aluminum by Protons.** E. C. CREUTZ, J. G. FOX AND R. SUTTON, *Princeton University.*—We have bombarded neon with 6-Mev protons and obtained a radioactivity of half-life 23 sec. ±2 sec. which we assign to $Na^{21}$ because all other energetically possible reactions on the three isotopes of neon lead to known periods > 1 minute. Since the nuclei $Na^{21}$ and $Ne^{21}$ differ only in the interchange of neutrons and protons, these isobars are of interest in connection with the hypothesis that the difference in energy of such nuclei is due solely to Coulomb forces. We have also bombarded Al with 6.2-Mev protons and observed the activity reported by Keurti and Van Voorhis[1] and assigned by them to $Si^{27}$. We obtain 4.9 sec.±1 sec. as the half-life. It should be pointed out that the isobars ($Si^{27}$, $Al^{27}$) are of the type mentioned above, with isotopic spin $-\frac{1}{2}$ and $+\frac{1}{2}$, respectively. These half-lives are of the order of magnitude to be expected from the calculated Coulomb energy differences of the isobars.

[1] G. Keurti and S. N. Van Voorhis, Phys. Rev. **56**, 614 (1939).

**61. A New Treatment of the Compound Nucleus.** H. A. BETHE, *Cornell University.*—In the past, the compound nucleus has always been treated using the dispersion method. This method describes very well the resonance phenomena but is unnecessarily complicated in the region of dense levels. We therefore propose here a continuum theory. The nucleus is described by a complex potential whose imaginary part gives the probability that a particle at a given point in the nucleus becomes amalgamated with it. The imaginary potential is assumed to fall off at the nuclear boundary gradually over a distance $l$ of the order of the range of the nuclear force, e.g., exponentially as $\exp[-(r-R)/l]$. This model gives sticking probability $\zeta=1$ for high energy in agreement with experiment. At lower energy, $\zeta=1-\exp(-2\pi l/\lambda\!\!\!^{-})$ for the exponential potential ($\lambda\!\!\!^{-}$=wave-length of incident particle). It is significant that $l$ occurs rather than the nuclear radius $R$; on the other hand, the occurrence of $2\pi l$ means that $\zeta$ remains of order unity down to rather low energies ($\approx$1 Mev). For $\lambda\!\!\!^{-}\gg 2\pi l$ the theory gives the $1/v$-law. For energies at which the levels become discrete, the theory must of course be replaced by the dispersion theory, and it gives meaning to the nuclear radius $R$ introduced by Peierls and Kapur and thus to the potential scattering.

**62. Interaction between Alpha-Particles.** HENRY MARGENAU, *Yale University.*—The interaction energy $V$ of two alpha-particles has been calculated as a function of the distance between their centers, these centers being assumed fixed in space. If the forces between elementary particles are taken to be of the customary form (ordinary+3 kinds of exchange), $V$ is in the first order a sum of 5 terms: $V_W+V_H+V_M+V_B+E_{\text{kin}}$. The last of these is always positive and arises from the promotion of the $s$ particles as the alpha-particles approach each other. $V_W$ and $V_B$ are always negative, the others positive. For any permissible choice of force constants the total $V$ is positive (repulsive forces). The first-order $V$ is zero at distances of separation about twice the range of nuclear forces; it rises to about 30 Mev for $R=0$. A second-order calculation yields attractive forces whose range is not, as is sometimes supposed, longer than that of the repulsive first order forces. Analogies with molecular problems break down for nuclei since the range of the forces is not large in comparison with the size of the nucleus. It is indeed quite insufficient to calculate the second approximation after the fashion of van der Waals forces without exchange. An estimate of the second-order forces leads to the conclusion that $V$ becomes sufficiently negative before it vanishes to allow the existence of a stable state of zero energy ($Be^{8}$). The scattering of alpha-particles in He is discussed on the basis of this type of interaction.

**63. Energy Levels Near the Ground State in $Co^{60}$ and $As^{76}$.** WILLIAM L. DAVIDSON, JR., *Yale University. (Introduced by Ernest Pollard.)*—Absorption studies have been carried out on the protons arising from the transmutation of Co and As under bombardment by 3.1-Mev deuterons from the Yale cyclotron. Since each element is composed almost entirely of a single isotope, the reactions involved are almost certainly

$$Co^{59}+H^{2}\rightarrow Co^{60}+H^{1}$$
$$As^{75}+H^{2}\rightarrow As^{76}+H^{1}.$$

The cobalt target was prepared by electrolytic deposition of the metal on a gold foil. Arsenic was sublimed onto a similar gold foil. The protons were detected by a method already described.[1] The table below lists the ranges of the proton "groups" from each target, the resulting "$Q$" values, and the indicated excitation levels in each residual nucleus.

| TARGET ELEMENT | RESIDUAL NUCLEUS | RANGES OF PROTON "GROUPS" (CM AIR) | "$Q$" VALUES (MEV) | EXCITATION LEVELS (MEV) |
|---|---|---|---|---|
| $Co^{59}$ | $Co^{60}$ | 42.0 | +2.75 | 3.03 |
| | | 60.0 | 4.03 | 1.75 |
| | | 88.5 | 5.78 | |
| $As^{75}$ | $As^{76}$ | 55.5 | 3.67 | 2.13 |
| | | 72.5 | 4.80 | 1.00 |
| | | 89.5 | 5.80 | |

It is seen that the average spacing of levels near the ground state is somewhat greater than 1 Mev. Investigations on the $(dp)$ reactions in other elements of medium atomic weight have given similar values.[1] This spacing is in general larger than one would expect for such nuclei on modern theories of nuclear structure. The advantages and limitations of the present method insofar as the resolution of "groups" is concerned will be discussed.

[1] W. L. Davidson, Jr., Phys. Rev. **56**, 1062 (1939).

## Saturday Afternoon at 2:00 o'clock

### Room 329

(For simultaneous session of the Optical Society, Room 428, see pages 27–28)

**64. A Simple Adiabatic Expansion Machine.** R. B. Jacobs* and S. C. Collins, *Massachusetts Institute of Technology.*—A simple free-piston type of adiabatic expansion machine has been developed for cryogenic use. Only three moving parts are used, and the operation takes place without lubrication. These features make the design particularly useful for working at extremely low temperatures. Camshaft, crankshaft and stuffing boxes have been eliminated entirely. The valve action is hydrostatic and the work is taken off by the recoil action of the piston upon the cylinder. Tests have shown the present machine to be over 50 percent efficient thermodynamically.

* Fellow of the Lalor Foundation.

**65. Theory of Terrestrial Magnetism.** D. R. Inglis, *Johns Hopkins University,* and E. Teller, *George Washington University.*—The theory based on electric currents within the earth, due to material convection guided by Coriolis forces,[1] is discussed and extended. The present heat flow through the crust does not permit as large speeds and temperature differences as inferred by Elsasser. Since it seems unlikely that the matter in two parts of a turbulent fluid, at the same level, is so different as to have a thermoelectric power comparable with that of two different metals at laboratory pressures, the ordinary thermoelectric effect seems inadequate. Other mechanisms, also depending on past or present Coriolis-guided convection, are proposed and seem to be more nearly adequate: (a) the convection within the core may make an undulatory surface of the core and at the same time maintain temperature differences between the junctions of the core and surrounding material; (b) upward and downward convection streams constitute hot and cold junctions between regions of high and low pressure, and thereby form a pressure couple to provide the required current.

[1] W. Elsasser, Phys. Rev. **55**, 589 (1939).

**66. Magnetic Susceptibility of Some Salts of the Iron Group at Low Temperature.** C. Starr, F. Bitter, and A. Kaufmann, *Massachusetts Institute of Technology.*—Preliminary measurements at liquid hydrogen temperatures (20.4°K) have been made of the magnetic susceptibility of the following salts: the chlorides of iron, chromium, nickel, cobalt, and manganese, and also manganous sulphide. The measurements were made by means of the nonhomogeneous field method described by Bitter and Kaufmann.[1] Measurements between 10,000 gauss and 30,000 gauss do not indicate a dependence of the susceptibility upon field strength for any of these salts. $NiCl_2$ showed no dependence from 5000 gauss to 30,000 gauss, and this result is in contradiction with the determination at Leiden.[2] The susceptibility of MnS lies on a continuation of the susceptibility curve determined by Squire[3] at higher temperatures, between the antiferromagnetic Curie point and liquid nitrogen boiling point. These measurements will be continued at other temperatures and at lower field strengths.

[1] Bitter and Kaufmann, Phys. Rev. **56**, 1044 (1939).
[2] Woltjer and Kamerlingh Onnes, Leiden Comm. No. 173b, c (1925).
[3] Squire, Phys. Rev. **56**, 922 (1939).

**67. Magnetization at Low Temperatures of Copper Containing 0.7 Percent Iron.** A. Kaufmann, F. Bitter, S. Pan, and C. Starr, *Massachusetts Institute of Technology.*—Previous measurements have indicated that the susceptibility of this alloy, when quenched to retain a solid solution, obeys a Curie-Weiss law at high temperatures and that a Curie temperature should exist at 150°K. Recent observations down to 20°K do not show ferromagnetism, but they do reveal a magnetization which is no longer proportional to the applied field. Further observations are required to clarify this situation, but it should be emphasized that this alloy is so dilute that 95 percent of the iron atoms have only copper atoms for nearest neighbors, the remaining 5 percent being in pairs surrounded by copper, and that no saturation effects of the magnitude observed are to be expected in a purely paramagnetic solution at 20°K in a field of 30,000 gauss. A further peculiarity is that when this alloy is aged, the precipitate is nonmagnetic, presumably $\gamma$-iron, but that at the very beginning of the aging process, long before there is appreciable precipitation, the susceptibility first increases by a factor of almost two, and then later drops to a very low value. This alloy has never shown the existence of a ferromagnetic component except when thoroughly aged, and then cold worked to transform the precipitate to $\alpha$-iron.

**68. Ferromagnetic Gold-Iron Alloys.** S. T. Pan, A. R. Kaufmann, and F. Bitter, *Massachusetts Institute of Technology.*—In the course of experiments on the aging of supersaturated solutions we have had occasion to prepare an alloy containing 63 atomic percent gold +37 percent iron, extending the range of compositions investigated by Shih.[1] In the quenched state this alloy is in the form of a solid solution. It was found to be ferromagnetic with a Curie temperature of about 230°C and an absolute saturation intensity of about 1 Bohr magneton per atom of the alloy. It seemed at first rather surprising that this face centered lattice should be ferromagnetic whereas $\gamma$-iron is not. However, it has been shown that the tendency to ferromagnetism increases as the ratio (atomic separation)/(radius of the $3d$ orbit) increases, and since the lattice constant of the above alloy is 3.94 A.U. (see Jette, Brunner and Foote[2]), while that of $\gamma$-iron is only 3.56, it is clear that conditions are favorable for ferromagnetism. The saturation intensity also seems reasonable if we assume that gold, like copper, contributes three electrons per atom to the iron lattice and that roughly three electrons per atom are required to reduce the mean magnetic moment of

iron to zero. Sixty percent of gold would reduce the magnetic moment of iron, 2.2 magnetons, by a little more than a half, leaving about one, as observed.

[1] Shih, Phys. Rev. **38**, 2051 (1931).
[2] Jette, Brunner and Foote, Trans. A.I.M.E. Inst. of Metals Div. 111, 354 (1934).

**69. A Modification of Heisenberg's Theory of Ferromagnetism.** F. BITTER, *Massachusetts Institute of Technology.*—Heisenberg's theory of ferromagnetism[1] breaks down at low temperatures[2] because of the assumption of a Gaussian distribution of states about the mean value of the energy which makes it possible for the system to assume states having energies approaching $-\infty$ which do not exist. This may be avoided by assuming the distribution of states to be given by binomial coefficients which can be made to vanish for assignable values of the energy. For instance, if we assume that the magnetization is given by $\mu(N_+-N_-)$ where $N_+$ is the number of atoms having a moment $\mu$ pointing to the right, $N_-$ the number pointing to the left; that the energy is given by a parameter $p$ such that $U=2Jp$, and that the spread in states is given by

$$n(I,p)=c\binom{aN_+}{bp}\binom{aN_-}{bp},$$

$a$, $b$, $c$ being constants determined by the calculable total number of states, mean value and mean square value of the energy, we find, using Heisenberg's results for these expressions

$$c=\binom{N}{N_+}\Big/\binom{aN}{aN_+};\quad \frac{a}{b}=\frac{Z}{2};\quad b=\frac{1-i^2}{3-i^2};\quad i=\frac{N_+-N_-}{N}.$$

$Z$=numbers of nearest neighbors; free energy $F$ given by

$$F(i,p,Z)=-\frac{8Jp}{Z}-aNKT\Big[\Big(2-\frac{1}{a}\Big)(x_+\ln x_+ + x_-\ln x_-)$$
$$-\Big(x_+-\frac{2p}{ZN}\Big)\ln\Big(x_+-\frac{2p}{ZN}\Big)-\Big(x_--\frac{2p}{ZN}\Big)\ln\Big(x_--\frac{2p}{ZN}\Big)$$
$$-\frac{4p}{ZN}\ln\frac{2p}{ZN}\Big];\quad x_+=\frac{N_+}{N};\quad x_-=\frac{N_-}{N}.$$

This expression leads to spontaneous magnetization at low temperatures for $Z>3.1$. The Curie temperature is defined by the equations

$$1-\frac{3}{Z}=\frac{1}{1+\sigma}-\tfrac{1}{2}\{(1+\sigma)\ln(1+\sigma)+(1-\sigma)\ln(1-\sigma)\};$$
$$\sigma=\tanh-\frac{6J}{ZKT}.$$

The free energy has a maximum for $i=0$ and all values of $T<T_c$, and the breakdown of the Heisenberg theory is consequently avoided.

[1] Zeits. f. Physik **49**, 619 (1928).
[2] Inglis, Phys. Rev. **42**, 442 (1932).

**70. Paramagnetic Relaxation and the Equilibrium of Lattice Oscillators.** J. H. VAN VLECK, *Harvard University.*—Calculations on the paramagnetic relaxation of chrome alum give qualitatively the proper variation of the relaxation time $\tau$ with field strength $H_0$ at liquid air temperatures. In the helium region $d\tau/dH_0$ has the wrong sign. This result is a general consequence of the thermodynamic model, in which the lattice oscillators are regarded as a thermostat. The failure regarding $d\tau/dH_0$ is probably intimately connected with the fact that the conservation of energy allows interchange between the spin and only oscillators of very low frequency, which constitute a small fraction of the total. Each such oscillator exchanges a quantum approximately $10^9$ times/sec. with spins, whereas an individual spin has about $10^3$ exchanges. These oscillators can preserve a constant temperature only if they have still more frequent exchanges with other oscillators, or with the walls. An adequate mechanism for such processes appears wanting. The situation is reminiscent of similar difficulties found by Peierls in the theory of electrical conductivity at low temperatures. If the oscillators serve as a thermostat, they have interruption frequencies comparable with their proper frequencies, so that the latter lose meaning. The attendant blurring out of the conventional frequency distribution $\rho_\nu=C\nu^2d\nu$ may possibly explain why the calculated value of $d\tau/dH_0$ has the wrong sign.

**71. Ferromagnetic Anisotropy and the Itinerant Electron Model.** HARVEY BROOKS, *Harvard University.*—Theories of ferromagnetism based on the Heisenberg model fail to provide a straightforward mechanism to account for the quenching of the orbital angular momentum, evidenced by the gyromagnetic ratio of 2 in ferromagnetics. It is shown that the energy of transfer of electrons between neighboring atoms, such as occurs in the energy band picture, is sufficient to lift the orbital degeneracy of the lower $d$ states in body-centered cubic structures. It is also shown that if the exchange energy be approximated by a Weiss molecular field, and the spin orbit interaction be introduced as a perturbation, the solution of the secular problem for the approximation of tight binding in the lower $d$ band leads to ferromagnetic anisotropy in the fourth approximation of perturbation theory.

**72. The Theoretical Susceptibilities of Metallic Lithium and Sodium.** J. B. SAMPSON AND FREDERICK SEITZ, *University of Pennsylvania.*—The free electron theory of metallic susceptibility is applied to lithium and sodium in an approximation that includes the effective electron masses, the exchange and correlation terms, and the Peierls-Wilson diamagnetic terms. Of the three Peierls-Wilson terms only the one corresponding to Landau's free electron diamagnetism is important. The exchange and correlation terms work in opposite directions, but the former predominates and increases the free electron paramagnetism by a factor of about two in the case of sodium and three in the case of lithium. The paramagnetic, diamagnetic and ion core terms are given in the table along with the observed susceptibilities. In the case of sodium, the result agrees closely with the experimental values, which vary by only about twenty percent. On the other hand, the experimental values for lithium vary over a sevenfold range and the theoretical value is greater than the largest.

TABLE
Contributions to the volume susceptibilities of lithium and sodium. (The values are given in c.g.s. units times $10^6$.)

| | Free Electron Para-mag-netism | Free Electron Dia-magnetism | Ion Core Dia-magnetism | Total | Observed |
|---|---|---|---|---|---|
| Lithium | 3.42 | −0.41 | −0.05 | 2.96 | 0.27−2.0 |
| Sodium | 1.01 | −0.20 | −0.18 | 0.63 | 0.51−0.63 |

**73. The Electric Quadrupole Moments of Gallium ($Ga^{69}$ and $Ga^{71}$).** NICHOLAS A. RENZETTI AND DONALD R. HAMILTON,* *Columbia University.*—The zero-moment method of atomic beams has been used to study the hyperfine structures (h.f.s.) of the ground $^2P_{\frac{1}{2}}$ state and the metastable $^2P_{\frac{3}{2}}$ state of the two isotopes of gallium. Six zero-moment peaks arising from the atoms in the $^2P_{\frac{3}{2}}$ state, three for each isotope, and two peaks from the atoms in the $^2P_{\frac{1}{2}}$ state, one for each isotope, were observed. It is found that the h.f.s. energy levels for the higher states show deviations from the interval rule and can be described by an equation of the form $E=(aC/2)+bC(C+1)$ where $C$ is the quantum-mechanical analogue of the cosine and "$a$" and "$b$" are the interval rule and nuclear quadrupole constants, respectively. These constants are determined by the values of the magnetic field at which the zero-moment peaks occur and have the following values:

| $Ga^{69}$ | | $Ga^{71}$ | |
|---|---|---|---|
| $b/a$ | $=0.0136\pm0.0004$ | $b/a$ | $=0.0068\pm0.0004$ |
| $b$ | $=(8.69\pm0.43)\cdot10^{-5}$ cm$^{-1}$ | $b$ | $=(5.51\pm0.39)\cdot10^{-5}$ cm$^{-1}$ |
| $a$ | $=(6.39\pm0.12)\cdot10^{-3}$ cm$^{-1}$ | $a$ | $=(8.11\pm0.11)\cdot10^{-3}$ cm$^{-1}$ |

From these numbers the h.f.s. separations are $\Delta\nu^{69}=(0.0362\pm0.0007)$ cm$^{-1}$ and $\Delta\nu^{71}=(0.0474\pm0.0007)$ cm$^{-1}$, and the quadrupole moments are $Q^{69}=0.20\cdot10^{-24}$ and $Q^{71}=0.13\cdot10^{-24}$ cm$^2$. The nuclear spins are verified to be $\frac{3}{2}$. From the peaks of the ground state it is found that $\Delta\nu_{71}/\Delta\nu_{69}=\mu_{71}/\mu_{69}=1.270\pm0.006$ and that these separations are $\Delta\nu^{69}=(0.0897\pm0.0011)$ cm$^{-1}$ and $\Delta\nu^{71}=(0.1139\pm0.0019)$ cm$^{-1}$. These numbers when substituted in the Goudsmit formula give for the nuclear moments $\mu_{71}=2.69$ and $\mu_{69}=2.11$ in nuclear magnetons.

* Now at Harvard University.

**74. The Nuclear Magnetic Moment of $N^{15}$.** J. R. ZACHARIAS AND J. M. B. KELLOGG, *Columbia University.*—We have made a determination of the nuclear magnetic moment of $N^{15}$ using a sample of $N_2$ gas containing 50 atomic percent $N^{15}$. The method and apparatus were the same as used for the work on the hydrogens.[1] Resonance curves were obtained at 0.5, 1 and 1.5 megacycles and yield values of $\nu/H$ which are independent of frequency. The $g$ value obtained is $0.560\pm1$ percent. Combining this with the spin of $\frac{1}{2}$ found by Kruger[2] and by Wood and Dieke[3] we obtain the value 0.280 nuclear magnetons $\pm1$ percent for $\mu(N^{15})$. Another sample of gas containing 70 atomic percent of $N^{15}$ gave the same result. It was shown experimentally that the resonance minimum identified with $N^{15}$ was not due to the $N^{14}$ in the sample. The theoretical value of $-0.26$ obtained by Rose and Bethe with a Hartree model is closer to 0.28 than the value obtained by the alpha-model. (See Sachs[4] for references.) The experiments do not yield a clear indication of the sign of $\mu(N^{15})$.

[1] Kellogg, Rabi, Ramsey and Zacharias, Phys. Rev. **56**, 728 (1939).
[2] H. Kruger, Zeits. f. Physik **111**, 465 (1939).
[3] R. W. Wood and G. H. Dieke, Phys. Rev. **55**, 1120 (1939).
[4] R. G. Sachs, Phys. Rev. **55**, 825 (1939).

## SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member one only of these will be assigned a place on the regular program while the others will be placed in a supplementary program to be called for if time permits.

The papers in the supplementary program may be called for only at the session indicated.

**75. The Effect of Deuterium and of Electric Discharges in Deuterium Oxide on the Sensitization of Photoelectric Cells.*** J. T. TYKOCINER AND L. R. BLOOM, *University of Illinois.*—The experiments with discharges in water vapor reported in Abstract No. 51 have been extended to different forms of discharges obtained with a.c., rectified pulses, d.c. and h.f. currents. Comparative measurements were also carried out with discharges in $D_2O$ vapor (99.8 percent), immediately following experiments with discharges in $H_2O$. By using in both cases the same pressures and applied potentials, similar results have been obtained in both cases. The increase in photo-sensitivity of a potassium surface due to discharges in $D_2O$ was of the same order of magnitude as that found for $H_2O$. The stability of cells sensitized by discharges in heavy water was found, in accordance with what was expected from theoretical consideration, to be greater than cells treated with $H_2O$ under similar conditions. Comparative experiments are being carried out with $H_2$ and $D_2$ thermally dissociated and their atoms acting directly upon alkali surfaces. Details of this investigation will be published in a Bulletin of the University of Illinois Engineering Experiment Station.

* To be read by title.

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## PROGRAM

FRIDAY, FEBRUARY 23, AT 10:00 A.M.

Pupin Physics Laboratories, Room 401

*Joint Session of the American Physical Society, the Optical Society of America and the Inter-Society Color Council*

**SYMPOSIUM**

**ON**

**OPTICAL METHODS FOR THE STUDY OF MOLECULAR STRUCTURE**

Invited Papers

1. **The X-Ray Diffraction Method.** B. E. WARREN, *Massachusetts Institute of Technology.*
2. **The Electronic Diffraction Method.** LOUIS R. MAXWELL, *Department of Agricultural Chemistry and Engineering of the U. S. Department of Agriculture.*
3. **The Band Structure Method.** R. BOWLING BARNES, *The American Cyanamid Company.*
4. **The Raman Spectra Method.** GEORGE M. MURPHY, *Yale University.*

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FRIDAY, FEBRUARY 23, AT 2:00 P.M.

Room 428

Contributed Papers

**1. An Optical Device for Rapid Placement of an Aircraft on a Line between Two Distant Points.** BRIAN O'BRIEN, *Institute of Optics, University of Rochester.* (15 minutes.)

To enable a pilot to place an airplane on a line between the sun and a ground station, a simple optical unit has been developed which has certain additional applications. A transparent triple mirror is formed by cementing three glass flats mutually perpendicular to each other, the joined edges being so cut that the boundary substantially vanishes when viewed in transmitted light. The triple mirror faces a fourth semi-transparent aluminized diagonal mirror, the axis of symmetry of the triple intersecting the diagonal mirror at 45°. A ray entering the system in either direction along this axis emerges along the perpendicular to this axis after reflection from the diagonal. An observer on the straight line joining two distant objects, viewing along the perpendicular to this line, thus sees the objects superimposed, one erect and one inverted, the superposition being undisturbed by any rotation of the optical system as a whole. The mirror system is mounted in a dust-tight housing of such dimensions that it can be held with rubber eye cup against one eye without obstructing the view ahead with the other. This permits maintaining the desired flight attitude of the airplane while observing the images

of the two distant objects, which approach and pass through each other as the airplane crosses the line of sight. A real field of 22° is secured, and since the superposition is not affected by movement or rotation, the instrument has proven very satisfactory even in rough air. In the original form as used for solar work the ground station is seen erect without magnification at approximately full brightness while the inverted image of the sun is attenuated by a factor of $5\times10^{-6}$ for comfortable observation. In a modified form with both images of equal brightness, the device has been applied to determine the distance of an aircraft above the top of an overcast by taking advantage of the depression of the horizon due to earth curvature.

**2. Total Emissivity of Various Materials.** B. T. BARNES, E. Q. ADAMS, AND W. E. FORSYTHE, *General Electric Company, Nela Park, Cleveland, Ohio.* (15 minutes.)

The test objects were flat sheets, heated by contact with a brass vessel containing water at 100°C or with a copper plate heated by an electric table stove. Radiant flux from a central area of 6 cm² fell on a thermopile. Adequate shutters, diaphragms and a cooling bath were provided; water vapor and $CO_2$ were driven out by a stream of nitrogen. The calibration source was a blackbody chamber surrounded with boiling water. A brass mirror of special shape, maintained at 100°C, reflected radiation from a blackened enclosure to the thermopile. The emissivity at 100°C is given for various metal, glass and pressed-carbon samples and for metal sheets coated with various radiator paints. Most metal samples tarnished when held at 300°C. Only carbon, quartz and glass samples could be heated to 500°C without surface changes. The emissivities of these samples are given below.

| | 100°C | 320°C | 500°C |
|---|---|---|---|
| Average for four carbon samples | 0.76 | 0.76 | 0.71 |
| Fused quartz | .78 | .80 | .75 |
| Corex-D glass | .80 | .80 | .76 |
| Nonex glass | .82 | .82 | .78 |

The total heat loss from painted and unpainted containers at 100°C was determined. From these data and the emissivity values, the loss by conduction and convection in still air was found to average 0.05 watt/cm².

**3. The Thermal Conductivities of Tungsten and Molybdenum at Incandescent Temperatures.** ROBERT H. OSBORN, *Hercules Powder Company.* (15 minutes.)

Worthing,[1] using an optical pyrometer method, found values for the thermal conductivity of incandescent tungsten which increased linearly with temperature. The present work was undertaken to check these values, and to extend his method to molybdenum. Results obtained for tungsten differed from those given by Worthing in that values obtained for the thermal conductivity decreased with increasing temperatures. This discrepancy is explained by the assumption that the use of certain empirical formulae deduced by Worthing to fit his data does not seem to be justified. Values found for tungsten range from 1.14 watts/(cm² K/cm) at 1300K to 1.03 watts/(cm² K/cm) at 2000K. Those for molybdenum range from 1.08 watts/(cm² K/cm) at 1200K to 0.67 watt/(cm² K/cm) at 1900K. In each case extrapolation of the function $k$ *vs.* $T$ (where $k$ is the thermal conductivity and $T$ is the absolute temperature) to room temperature yields values of $k$ in reasonable agreement with those obtained by other workers. Resistivities obtained for tungsten were found to be in excellent agreement with values given by Forsythe.[2] Those for molybdenum were uniformly lower than the values given by Worthing.[3] This may be explained by differences in the purity of the wire in the two cases.

[1] A. G. Worthing, Phys. Rev. **4**, 535 (1914).
[2] W. Forsythe, J. Opt. Soc. Am. **24**, 114 (1934).
[3] A. G. Worthing, Phys. Rev. **25**, 846 (1925).

**4. Tables of Planck's Radiation and Photon Functions.*** A. N. LOWAN AND G. BLANCH, *Work Projects Administration, New York City.* (10 minutes.)

Several recent papers on photon emission and blackbody radiation by A. G. Worthing and Frank Benford made it seem timely to compute Planck's functions of radiation and photon emission. Let $f(w)=[(\exp\ c_2/wT)-1]^{-1}$; $R_w=c_1w^{-5}f(w)$, $N_w=2\pi cw^{-4}f(w)$, where $c_1$ and $c_2$ are the well-known radiation constants, $w$ is the wave-length (usually denoted by the Greek letter lambda), $T$ is the absolute temperature and $c$ is the velocity of light. Clearly, $R_w$ is the intensity of blackbody radiation, and $N_w$ is the corresponding intensity of photon emission. Further, $R_{0-w}$ and $N_{0-w}$ denote the integral of $R_w dw$ and $N_w dw$, respectively, from zero to $w$. The authors computed three tables: Table I: The ratios $R_w/R_{w\ \max}$, $N_w/N_{w\ \max}$, $R_{0-w}/R_{0-\infty}$, $N_{0-w}/N_{0-\infty}$ for the following ranges and intervals of the argument $wT$ $=0.050(0.001)0.100$; $0.100(0.005)0.400$; $0.400(0.010)0.700$; $0.700(0.020)1.000$; $1.00(0.050)2.00$ cm-deg. K. Table II: The functions $R_w$, $N_w$, $R_{0-w}$, $N_{0-w}$ for $T=1000$°K and $w$ ranging between 0.50 and 20.0 microns. (This table is coextensive with Table I.) Table III: $N_w$ for 42 values of $w$ ranging from 0.25 to 10.00 microns, and $T=1000$, 1500, 2000, 2500, 3000, 3500, and 6000°K. The following values of the constants were adopted, after consultation with H. T. Wensel and Lyman J. Briggs of the National Bureau of Standards: $c_1=3.732\times10^{-5}$ erg cm$^{-2}$ sec.$^{-1}$; $c_2=1.436$ cm-deg. K. The tables are given to five significant figures, with first and second differences. There has also been included in the introduction to the tables a discussion about the number of significant figures which are reliable in various parts of the range, on the basis of the extent of uncertainty in the values of the constants $c_1$ and $c_2$, as well as a correction table for a change in $c_2$. The computations have been made by the Project for the Computation of Mathematical Tables, New York City, under the sponsorship of Dr. Lyman J. Briggs, Director of the National Bureau of Standards, with A. N. Lowan as the technical director.

* The present paper will appear in full in J. Opt. Soc. Am.

**5. Clinical Blood Pharmacology After Treatment with X-Rays.** DAVID I. MACHT, *Pharmacological Research Laboratory, Hynson, Westcott & Dunning, Inc., Baltimore.* (12 minutes.)

In a previous communication before this Society (February 19, 1938) the author reported the pharmacological results he obtained in studies on blood specimens taken from

normal animals before and after their treatment with x-rays. Special phytopharmacological tests revealed that such samples contained a toxic substance appearing twelve hours or more after the subjects from whom they were taken had been exposed to x-rays. Discovery of this toxin suggested that it may play a role in the causation of Roentgen sickness. In the present paper the author reports the findings obtained in similar studies on blood specimens secured from human patients suffering from malignant and non-malignant affections, respectively. Blood specimens taken from all these cases after irradiation revealed a greater toxicity than that exhibited by the sera obtained from the same individuals before initiation of treatment. Of further interest were tests made on samples of blood taken from a dozen technicians employed in x-ray departments. The latter gave a marked phytotoxic reaction although the subjects from whom they had been obtained were in apparently good health.[1]

[1] D. I. Macht and M. B. Livingston, J. Gen. Physiol. 4, 573 (1922); D. I. Macht, Protoplasma 27, 1 (1937); Proc. Soc. Exper. Biol. & Med. 39, 1 (1938); Am. J. Roentgenol. 41, 709 (1939).

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## SATURDAY, FEBRUARY 24, AT 10:00 A.M.

## Room 428

**6. The *Komplextheorie* of Visual Sensation.*** A. H. HOLWAY AND M. J. ZIGLER, *Wellesley College.* (15 minutes.)

Recent statements concerning the "new science of seeing" as opposed to the science of vision have completely overlooked one of the most outstanding attempts in the history of thought to formulate a comprehensive understanding of the facts of vision (=seeing). This formulation is the *Komplextheorie* of the late George Elias Müller. In formal outline the *Komplextheorie* is descriptive in nature in the same sense as the allegedly "new" proposals. Müller's theory, however, is much more comprehensive. From the time of its inception (*ca.* 1879) to the last decade (1934), this theory in its explanatory aspects has placed greatest emphasis upon variables within the organism, variables which occasion significant, detectable, and often measurable variations in visual sensation. Thus, to propose a "new science of seeing" on the ground that these variables have been overlooked by investigators of vision is not only to exhibit a marked lack of historical perspective but also to found the discipline on a basis which has no real existence. Müller proposed his theory about 1879, and continued to develop the fundamental ideas right up to his death in 1934. The present exposition is made with the sole purpose of acquainting investigators with the general principles of the theory as stated in Müller's latest works.[1]

* The present paper will appear in full in Psych. Rev.

[1] *Darstellung und Erklärung der verschiedenen Typen der Farbenblindheit, nebst Erolerung der Funktion des Stäbchenapparates sowie des Farbensinns der Bienen und der Fische* (Vandenhoeck and Ruprecht, Göttingen, 1924), pp. ix+216; *Über die Farbenempfindungen, Psychophysische Untersuchungen, Zeits. f. Psych. u. Phys. d. Sinnesorgane,* Erganzungsbander **17–18**, xviii+648 (1930); *Kleine Beitrdge zur Psychophysik der Farbenempfindungen* (Barth, Leipzig, 1934), pp. iv+316.

**7. The Spectral Sensibility of the Long-Eared Owl.*** MAURICE HENRI PIRENNE[1] AND SELIG HECHT, *Laboratory of Biophysics, Columbia University.* (20 minutes.)

The owl's retina contains only rods, and its nocturnal habits have generally been correlated with this fact. Its sensibility distribution in the spectrum as determined by Piper in terms of retinal potentials follows that of other night birds and corresponds to the absorption and bleaching of visual purple in the spectrum. This whole picture was called into question by the report of Vanderplank that the owl is mainly sensitive to the infra-red of the spectrum. However, Vanderplank's work must be in serious error. First, Matthews and Matthews have shown that the far infra-red produces no retinal potential in the owl's eye. Second, we have now found that the near infra-red also produces no visual effect. We have further investigated the matter by determining the sensibility distribution of the owl's eye in the spectrum. Our method follows that of Vanderplank in using the iris contraction of the intact animal as a criterion of stimulating action. Exposure to different parts of a continuous spectrum isolated by Wratten and Corning filters shows not only that the owl is insensitive to the infra-red, but that its sensitivity to red and orange is low compared to its sensitivity to green and blue-green, and that its maximum sensitivity is near 515 mμ, much as is to be expected from the rod nature of its retinal elements. Calling 1.00 the energy at 533 mμ necessary to elicit a minimal contraction of the iris, then the necessary energy at 451 mμ is 3.27; at 490 mμ it is 1.18; at 576 mμ, 3.72; at 631 mμ, 39.5; at 652 mμ, 215.8; and at 683 mμ, 6223.0. Between 750 mμ and 2000 mμ even a relative energy content of 500,000 fails to elicit the slightest contraction in the dilated pupil of the owl. The iris contracts strongly when the eye is exposed to ultraviolet of 360 mμ. Whether this corresponds to actual vision or only to the fluorescence of the ocular media remains to be decided.

* The present paper will appear in full in J. Gen. Physiol.

[1] Fellow of the Belgian American Educational Foundation.

**8. Size of Pupil as a Variable Factor in Measurements of the Threshold. An Experimental Study of the Stiles-Crawford Phenomenon.*** LOUISE L. SLOAN, *Wilmer Institute, Johns Hopkins Medical School.* (15 minutes.)

The studies of Stiles and Crawford and others[1] have shown that under certain experimental conditions the peripheral zones of the pupil show an apparent decrease in luminous efficiency. As a result, the brightness response of the eye is not directly proportional to the area of the entrance pupil. Under other experimental conditions, however, the different pupillary zones show an apparently equal

luminous efficiency and the brightness response of the eye is therefore directly proportional to the area of the entrance pupil, as was previously believed to be true under all experimental conditions. The present study was undertaken to investigate the Stiles-Crawford phenomenon under experimental conditions which are directly applicable to determinations of the achromatic threshold, and in particular to the measurements obtained with the light sense tester devised by the author.[2] Experimental determinations of the achromatic threshold were made with a series of different sizes of pupil. Measurements were made at the fovea and in a paracentral region of the retina, with white, blue and red light. The data indicate that, within the accuracy of the measurements, the product, threshold times area of entrance pupil, is a constant. It is therefore possible to reduce all threshold measurements made with different sizes of pupil to a comparable basis if the diameter of the entrance pupil is known. A camera and auxiliary apparatus for photographing the pupil in the dark are described.

* The present paper will appear in full in Arch. Ophthal.
[1] W. S. Stiles and B. H. Crawford, Proc. Roy. Soc. **B112**, 428–450 (1932–33); W. S. Stiles, Proc. Roy. Soc. **B123**, 90–118 (1937); B. H. Crawford, Proc. Roy. Soc. **B124**, 81–96 (1937).
[2] L. L. Sloan, Arch. Oph. **22**, 228–251 (1939).

**9. Experimental Determination of the Faithfulness of a Three-Color Reproduction.** S. Q. DUNTLEY AND ARTHUR C. HARDY, *Massachusetts Institute of Technology.* (15 minutes.)

The adoption of certain resolutions by the I. C. I. in 1931 signalized the beginning of an extensive use of tristimulus values for the specification of color. This type of specification finds its most natural use in connection with problems arising in the field of three-color reproduction. Because each color of the original subject is reproduced by a mixture of three primaries, a spectroradiometric match between original and reproduction is too exacting a requirement. Instead, a subjective match under specified conditions must be accepted as the criterion of perfection. Testing the faithfulness of a color process by spectrophotometry and subsequent integration is a straightforward procedure when the original and the reproduction employ the same type of illuminant. For example, the color process may be adapted to exposure by tungsten light and projection by tungsten light. This paper deals largely with the procedure of testing when the color process is adapted for exposure to light of one quality and projection by light of another quality.

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## SATURDAY, FEBRUARY 24, AT 2:00 P.M.

## Room 428

**10. Warmth and Coolness of Colors.** SIDNEY M. NEWHALL, *Johns Hopkins University.* (10 minutes.)

A circular chart of 50 color samples comprising the so-called Munsell "maxima," which are approximately equi-stepped throughout the hue circuit, was inspected individually by 297 observers. The instructions called for: (a) a decision as to which color suggested the greatest impression of thermal warmth, *viz.*, which color seemed warmest, (b) which color seemed coolest, and (c) any plausible reasons for the selections made. The results are as follows: (a) The "warmest" judgments show a minor mode in the violet at 420 mu, but a strikingly major mode in the red-orange region at 610 mu. (b) The "coolest" judgments exhibit no such marked mode, but range irregularly all the way from yellow through green and blue to purple. There are, however, some indications of peaking in the yellow around 572 mu, the green at 552, and the blue at 476. (c) Outstanding natural sources of temperature stimulation which were mentioned, like the sun and fire, are largely confined to the red to yellow region, whereas prominent cool objects, like open water and shady vegetation, appear to range through the green, blue and into the purple. The relatively great hue-range covered by such perceptually cool objects provides opportunity for the psychological association of coolness with a relatively great range of hues. This may be the explanation of the striking disagreement concerning the "coolest" color.

**11. Application to Dyes of the ISCC Method of Specification of Filters.*** I. H. GODLOVE, *E. I. du Pont de Nemours & Co., Inc.* (10 minutes.)

The ISCC method[1] has been extended and applied to the rapid filing and reference to spectral transmission curves of various shapes and to identification of unknown dyes. This elaboration has been very briefly described.[2] The transmission scale is divided into 15 unequal intervals designated by digits and letters in a way easily remembered. These are read at nine wave-lengths; and the designation is used as an indexing tab. All solutions of known and unknown dyes are adjusted, without weighing, to a minimum of ten percent corrected transmission. A library of curves of soluble dyes on the American market having been built up, it is possible to identify unknown relatively pure dyes in a few minutes, using a few milligrams of material. The designations also permit very rapid location of dyes having a desired shape of spectral transmission curve, being useful thereby in picking out filter dyes and in similar problems. They facilitate study of the relation of light absorption and chemical constitution. With a little experience the shape of the curve is easily visualized from the designations. For example, the two following designate, respectively, a yellow with a very sharp "cut-off" and a nearly "neutral" dye:

| | |
|---|---|
| 339KAAAAA | "Pontacyl" Light Yellow GX |
| 554544456 | Du Pont Nigrosine WSJ powder. |

Examples of curves and applications of the method will be given.

* The present paper will appear in full in J. Opt. Soc. Am.
[1] D. B. Judd, J. Opt. Soc. Am. **28**, 390–7 (1938).
[2] Inter-Society Color Council News Letter No. 28 (Dec., 1939).

**12. Lighting for the Detection of Small Color-Differences.** A. H. TAYLOR, *Lighting Research Laboratory, General Electric Company, Nela Park, Cleveland.* (20 minutes.)

One of the commonest types of industrial color-matching in its broadest sense involves comparisons of colored objects differing only slightly in spectral reflection. The pairing of silk stockings in a hosiery factory is a good example. A theoretical treatment of this problem would indicate that the light best adapted to the detection of small color-differences of this character would be one rich in energy in the spectral region of maximum absorption by the colored object. This has been amply verified by a recent research in this laboratory. In a study of fading of dyed textiles by artificial light it was found that small amounts of fading of blue textiles were more easily detected under tungsten lamps than under fluorescent daylight lamps, but the fluorescent daylight lamp was superior when the textiles were pink or red. This study is being expanded to include a wide range of colored textiles and the results will be demonstrated.

BIBLIOGRAPHY: John C. Gehant, *"Thoughts on Color-Matching,"* Paint, Oil and Chem. Rev. (December 7, 1939), p. 9.

**13. Applications and Accuracy of Three-Filter Photoelectric Colorimetry.** RICHARD S. HUNTER, *National Bureau of Standards.* (15 minutes.)

Previous papers[1] have described the choice of three filters for approximate photoelectric tristimulus colorimetry with the G.E. barrier-layer photo-cell and incandescent source at 3100°K. These filters have been used with a multipurpose reflectometer:[2] (1) To derive approximate I.C.I. tristimulus specifications of surfaces, (2) To derive trilinear coordinates in a uniform-chromaticity-scale system, (3) To determine magnitudes of color difference (in NBS units[3]) between pairs of surface colors, (4) To measure whiteness of white and near-white surfaces, and (5) To measure yellowness of white and near-white surfaces. Steps in the computation of each of these quantities will be illustrated and sources of error will be noted. Chief in importance among the sources of error is failure of the source-filter-photo-cell combinations to duplicate spectrally the I.C.I. standard observer for colorimetry. Magnitudes of error from this source may be held to a minimum by choosing standards which are spectrally similar to the samples to be measured. When such standards are chosen, errors in the derivation of I.C.I. values are of the order of one-tenth the distances between the point representing the standard and those representing the respective samples on the $(x,y)$-diagram.

[1] R. S. Hunter, J. Opt. Soc. Am. **28**, 51 and 179 (1938).
[2] R. S. Hunter, J. Opt. Soc. Am. **27**, 225 (1937).
[3] D. B. Judd, Am. J. Psychol. **52**, 418 (1939).

# Inter-Society Color Council

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## PROGRAM

Sessions to be held in Hendrick Hudson Room of the Roosevelt Hotel, New York City, *except* Wednesday evening session (see Wednesday evening program).

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WEDNESDAY, FEBRUARY 21, AT 2:00 P.M.

Hendrick Hudson Room, Roosevelt Hotel

TECHNICAL SESSION ON SPECTROPHOTOMETRY IN THE PULP AND PAPER INDUSTRY

*Jointly Sponsored by the Inter-Society Color Council and the Technical Association of the Pulp and Paper Industry*

*Chairman:* John L. Parsons

Invited Papers*

**1. Introduction. Dialogue between Mr. Papermaker and Mr. Meter.** D. B. JUDD AND L. C. LEWIS. (8 minutes.)

The color of paper may be adjusted to match a standard by addition of dye to the beater furnish. This adjustment may often be made successfully by visual comparison of trial sheets with the standard, provided the dyes used for the standard are also used in the beater. But if the dyes used for the standard are unknown a spectrophotometer may provide a more economical way to obtain a match than direct visual comparison.

**2. Survey of Instruments—Spectrophotometers.** K. S. GIBSON, *National Bureau of Standards.* (30 minutes.)

Recent progress in spectrophotometry in the visible spectrum has been largely along photoelectric lines. Most of these new instruments, however, have been designed for transmission measurements only, and are of little direct interest to the pulp and paper industry. Reference is made to various previous surveys of spectrophotometry and the present paper merely brings the subject up to date, with particular emphasis on reflection measurements. Visual spectrophotometric measurements have proved inadequate for the accurate colorimetric specification of white and near-white materials. The colors of such materials are importantly affected by small changes or differences of spectral reflection, differences that are of the order of magnitude of the uncertainties inherent in visual spectrophotometry. The photoelectric cell, on the other hand, is ideally adapted to the determination of small differences, and in apparatus designed on sound electrical and optical principles is capable of yielding spectrophotometric measurements that are both precise and accurate. All reflection spectrophotometers measure the apparent reflectance of a material relative to the apparent reflectance of a working standard, under certain fixed conditions of illumination and observation. The concept of apparent reflectance, the importance of considering the most desirable conditions of illumination and viewing, and the question of primary and secondary standards of apparent reflectance, are accordingly briefly considered.

**3. Survey of Instruments—Abridged Spectrophotometers.** J. A. VAN DEN AKKER, *Institute of Paper Chemistry.* (30 minutes.)

"Abridged spectrophotometer" is defined as a spectrophotometer in which light filters passing relatively narrow

* All papers of this session will be published in the Paper Trade Journal and Technical Association Papers.

wave-length bands are employed instead of a prism or grating monochromatic illuminator. Instruments of this type may be classified according to their optical or spectral characteristics, geometry of illuminating and viewing of the sample, and method of measurement of light intensity or photometry. Similarly, instrumental discrepancies may be regarded as compounded of errors of the three classes: spectral, geometrical, and photometrical. The spectral characteristics of an instrument are those which depend upon wave-length of light. These characteristics determine the error in reflectance or transmittance intrinsic to the broad wave-length band passed by a filter. The spectral error depends also upon the spectral reflectance or transmittance curve over the range of wave-lengths passed by the filter. When this portion of the curve is a straight line, the effective wave-length for the instrument is that wave-length at which a true spectrophotometer gives the same result as that obtained by the abridged spectrophotometer. In comparing instruments of the same kind, it is convenient to consider spectral errors in terms of discrepancies in effective wave-length. "Geometry" of an instrument refers to the distribution of light energy over all angles of incident and reflected light, to the angle of incidence, and to the type of spatial arrangement for "viewing" the sample. Differences between the geometry of instruments of different design account for quite appreciable differences in reflectance, and such differences in instruments of the same kind are responsible for the geometrical error. The third component of instrumental error, namely, the photometrical error, depends upon the method of photometry employed. In routine control, where only precision and reproducibility are required, abridged spectrophotometers are in many cases adequate; they are not, however, sufficiently accurate for absolute color measurement. The spectral, geometrical, photometrical, and other characteristics of available abridged spectrophotometers are given.

**4. Survey of Instruments in Use in the Pulp and Paper Industry.**

This report will be compiled from answers to questionnaires, and will be published with the papers of this session.

**5. Use of Instruments: In Pulp.** R. S. HATCH, *Weyerhaeuser Timber Company.* (25 minutes.)

Both bleached and unbleached pulp may be considered as a raw material for further processing into finished articles of commerce. The problem of evaluating the color of pulp is one which involves the exact physical measurement of the color rather than the expression of color values in psychological terms. The best instrument and the instrument to which all physical measurements of color should be referred is an automatic recording spectrophotometer. Under certain conditions, where pulp is being produced from a single species, an abridged spectrophotometer may be used for general research purposes and a properly designed brightness meter may be used for manufacturing control. Brightness meters should be so constructed that commercial samples of the pulp itself can be directly measured without resorting to the making of special color sheets from the sample in question. Brightness meters in general could be improved by recommended changes in the illuminating system. In any kind of color measuring instrument in which photocells are employed, care must be taken to avoid dirt or foreign matter of any kind in that portion of the sample which is illuminated for test. Standard methods for the determination of dirt have been developed and are in common use; but in measuring the color of pulp, dirt should not be included since a true measure of the color is that of the mass of fibers themselves free from foreign matter.

**6. Use of Instruments: In Beater Furnish.** R. N. GRIESHEIMER, *Mead Corporation.* (25 minutes.)

Instrumental methods of controlling the color of beater furnishes are contrasted with the older method of visual control. Although the advantages of the instrumental methods are indisputable, neither method can be wholly successful in providing for color control of the finished sheet of dyed paper unless account is taken of certain machine variables that affect sheet color by influencing dye retention, etc. Important variables are the *p*H and freeness (refining treatment) of the to-wire stock. Instrumental methods are subdivided into empirical methods, and methods involving the absolute calculation of certain optical constants of the raw materials and finished sheet from either the Kubelka-Munk theory or the theory of Trichromatic Coefficients. The latter methods are principally of academic interest and have not met wide-spread use in the industry. Two empirical methods are outlined, both depending on the ability of a technical man to associate various dyestuffs with the shapes of their spectrophotometric curves, and the displacements of these curves with changes in dye concentrations. A particular instrumental method called the card index system is discussed in considerable detail. A program for indexing variations in reflectance at certain wave-lengths with weight of dye producing these changes for a given furnish is set up. It is then indicated how these data, considered with other data taken on the effect of important machine variables, can be used for predicting the color of the finished sheet. A double integrating sphere reflectometer and a time-saving wet pulp sampling procedure are briefly described as tools found useful in applying the card index system. In conclusion, general aspects of the problem are discussed including considerations of start-up losses due to off-color, color tolerances, and the selecting of a method and instruments to fit a particular mill's requirements.

**7. Use of Instruments: In Uncoated Paper.** MYRL N. DAVIS, *Kimberly-Clark Corporation.* (25 minutes.)

This discussion is limited to the use of spectrophotometers and colorimeters in the design and control of "white," uncoated papers. Experience has shown that a working estimate of the apparent "whiteness" of paper can be obtained by measurement of reflectance with light of 458 millimicrons wave-length. Instrumentation is available and widely used for making such single measurements on paper samples in controlling the uniformity of paper being manufactured. Hue of the paper is still controlled visually in all

but a few paper mills. It is possible, by use of the Guerivic, Kubelka and Munk, Smith theory of the optical properties of diffusely reflecting materials, to determine scattering and absorption coefficients for the pulp and pigment of which paper is manufactured and by use of these coefficients to predict the reflectance and opacity of papers made from any proportions of these raw materials. Examples are given of such predictions for machine made papers, the optical coefficients having been obtained from simple hand made papers. The effect of supercalendering on opacity and color is discussed. Exact quantitative estimates of the effect of supercalendering are not yet possible.

**8. Use of Instruments: In Coated Paper.** WILLIAM J. FOOTE, *Consolidated Water Power and Paper Company.* (25 minutes.)

By means of spectral reflectance curves, dyestuffs may be identified either in coated or uncoated papers and rough quantitative estimations made. In addition, spectral reflectance curves may be used to specify the color of standard grades, to act as a guide in color matching in general, and particularly in the case of matching the color of base sheet and coating of tinted whites, and to indicate tolerances. A more precise method of specifying standard colors and tolerances consists of using chromaticity diagrams based on the specification of color by the method proposed by the International Commission on Illumination in 1931. By the use of one additional measurement (either $R_0$ or $R_{.98}$ at any chosen wave-length) and calculations involving the Kubelka and Munk relationship, valuable information is obtained on the fundamental optical coefficients (scattering and absorption) of coatings made up with various types of pigments. This permits a study of the effects of different raw materials and the successive steps in the process of manufacture on color, gloss, and opacity of the finished product. The relation of the physical measurements, brightness (G.E.R.M.) and visual efficiency ($Y$), with visual "brightness" and "whiteness" and the possibility of there being an optimum color for white printing papers are briefly discussed.

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## WEDNESDAY EVENING, FEBRUARY 21, AT 8:00 P.M.

### Auditorium of the Electrical and Gas Association of New York, 480 Lexington Avenue, New York City

(Note change in place of meeting. Admission to the evening session is by ticket only, but those tickets may be procured without cost from the secretary of the Council, or at the registration desk.)

### POPULAR SESSION: PARADE OF COLOR

*Chairman:* Carl E. Foss

**9. Highlights of Color Reproduction History.**

This is a presentation in radio style recreating the scenes of the first color printing, LeBlon's development of the mezzotint process, Maxwell's suggestion of photographic methods to reproduce the colors of objects, and the application of the principles of LeBlon and Maxwell by F. E. Ives in his halftone screen printing process. Following the highlights of past centuries, a typical production problem of recent times is presented. The difficulties due to unstandardized steps in the various processes are portrayed and the introduction of standard methods is made. The presentation ends with a look at the future.

**10. Color Reproduction Fundamentals.** F. L. WURZBURG, JR., *Interchemical Corporation Research Laboratories.*

This is a review of the principles of the various additive and subtractive methods of color reproduction from both the objective and subjective standpoints. It will be shown how the development of the sciences of colorimetry and spectrophotometry have recently contributed materially to a better understanding of the theoretical requirements which any truly accurate and automatic method of color process must fulfill. The simplification of the artist palette by the utilization of the principles of three-color mixture so long used in the processes of automatic color reproduction will be explained.

**11. Science Visits the Artist.** WILLIAM L. LONGYEAR, *Department of Advertising Design, Pratt Institute.*

This is a report of the findings of an artist-industrial designer who visited the summer art colonies to study the reaction of a trichromatic palette. Demonstrations were given at art association meetings and the opinions of the established artists as well as the students were obtained. Paints made with the trichromatic palette will be shown.

## THURSDAY, FEBRUARY 22, AT 9:30 A.M.

Hendrick Hudson Room, Roosevelt Hotel

### DISCUSSION SESSION

*Chairman:* Deane B. Judd

12. **Applicability of the Inter-Society Color Council System of Color Names**
    - To microscopic structures (Kelly)
    - To biological descriptions (Farnsworth)
    - To soils (Nickerson)
    - To transparent media (Gage, Kelly)
    - To translucent and fluorescent media (Kelly)
    - To opaque ceramic products (Robertson)
    - To textiles (Pinnell, Scott, Rorke).
13. **Determination of the ISCC Color Names for All of the Samples of the Maerz and Paul Dictionary of Color** (Nickerson, Rorke, Robertson).
14. **Determination of the ISCC Color Names for All of the Standard Colors of the Textile Color Card Association** (Rorke, Pinnell, Scott).
15. **Definition of the ISCC Color Names in Terms of the Colorimetric Coordinate System Recommended in 1931 by the International Commission on Illumination** (Kelly, Gage).
16. **Development of Color Tolerances**
    - For paint (Paul, Hunter)
    - For tinted papers (Loveland)
    - For carton and label printing (Beck)
    - For textiles (Scott, Pinnell)
    - For ceramic products (Hunter, Robertson)
    - For photographic film (Dimmick).
17. **Preparation and Publication of a List of Basic Color Terms with Preferred ISCC Definitions** (Dimmick, Pinnell).
18. **Terms for Uses of Artificial Daylight** (Macbeth, Gage).
19. **Illumination for the Detection of Small Color Differences** (Taylor, Nickerson).
20. **Development of a Standard Test for Ability to Discriminate Small Color Differences** (Le Grand Hardy, Foss, Scott, Pinnell, Newhall, Dimmick).

*The individuals named have agreed to speak briefly (2–5 minutes) on the subjects listed.*

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## THURSDAY, FEBRUARY 22, 1:00 P.M.

Hendrick Hudson Room, Roosevelt Hotel

Luncheon groups to continue informal discussion of problems raised during morning session.

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## THURSDAY, FEBRUARY 22, 2:30 P.M.

Hendrick Hudson Room, Roosevelt Hotel

### BUSINESS SESSION

Reports of Officers, of Retiring Chairman, News Letter Editor, Committee Chairmen.
Reports of chairmen of delegates from each member group will be called for:

American Association of Textile Chemists and Colorists, W. M. Scott
American Ceramic Society, V. H. Remington
American Psychological Association, F. L. Dimmick
American Society for Testing Materials, M. R. Paul
Illuminating Engineering Society, H. P. Gage
National Formulary, American Pharmaceutical Association, D. C. Beach
Optical Society of America, I. H. Godlove
Society of Motion Picture Engineers (to be announced)
Technical Association of the Pulp and Paper Industry, J. L. Parsons
The Textile Color Card Association of the United States, Inc., M. H. Rorke
U. S. Pharmacopoeial Convention, H. C. Muldoon
Individual Member Group, Le Grand H. Hardy

FRIDAY, FEBRUARY 23, 10:00 A.M.

Pupin Physics Laboratories, Columbia University

Room 401

*Joint Session of the American Physical Society, the Optical Society of America and the Inter-Society Color Council*

## SYMPOSIUM

## ON

## OPTICAL METHODS FOR THE STUDY OF MOLECULAR STRUCTURE

Invited Papers

1. **The X-Ray Diffraction Method.** B. E. WARREN, *Massachusetts Institute of Technology.*
2. **The Electronic Diffraction Method.** LOUIS R. MAXWELL, *Department of Agricultural Chemistry and Engineering of the U. S. Department of Agriculture.*
3. **The Band Structure Method.** R. BOWLING BARNES, *The American Cyanamid Company.*
4. **The Raman Spectra Method.** GEORGE M. MURPHY, *Yale University.*

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